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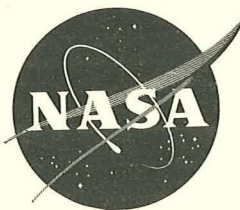
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NASA General Working Paper No. 10,039

SOME DECELERATION TRANSMISSION CHARACTERISTICS OF
NYLON AND DACRON RASCHEL NETTING AND SOMYK
LOOP FABRIC UNDER IMPACT DECELERATION,
AT IMPACT VELOCITIES OF 13.9 AND 30 FEET
PER SECOND

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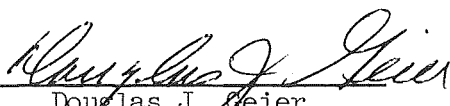
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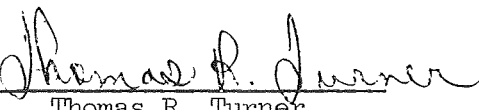
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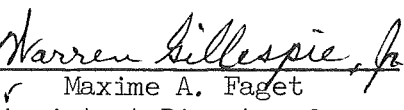
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SOME DECELERATION TRANSMISSION CHARACTERISTICS OF NYLON AND DACRON
RASCHEL NETTING AND SOMYK LOOP FABRIC UNDER IMPACT DECELERATIONS,
AT IMPACT VELOCITIES OF 13.9 and 30 FEET PER SECOND

Douglas J. Geier, Thomas R. Turner and Walter D. Salyer

SUMMARY

To determine the feasibility of netting type fabrics to be used as crew couches under impact decelerations, drop tower tests have been conducted on couches fabricated from Nylon and Dacron Raschel netting and Somyk Loop fabric. Control data was gathered by testing, to comparable g levels, a Mercury type torso support. An anthropometric dummy was used as a couch occupant.

The tower carriage, couch and dummy assembly was dropped onto aluminum honeycomb which absorbed the energy. Energy inputs were varied by varying drop heights. Induced forces were changed by varying the cross-sectional area of the honeycomb. Transverse decelerations were recorded and measured at the carriage impact surface, approximate center of gravity of the couch frame, dummy chest, and dummy head.

A total of 60 drop tests were conducted during this program and a representative sampling of the data is presented in this report.

Inspection of the data indicates that Somyk fabric demonstrates the capability of attenuating the impact forces by mechanical friction and/or permanent elongation of the fabric. This elongation, with minimal elastic return, is caused by molecular realignment within the fibers. Through the proper design of Somyk fabric for the mass distribution of the human body, the velocity and energy induced by landing loads could be dissipated by uniform displacement of the human body as required to keep the accelerative forces within existing human tolerance limits.

SYMBOLS AND ABBREVIATIONS

a	- Decelerative force
DRF	- Dynamic Response Factor between carriage impact surface loads and loads measured on dummy - $DRF = G_{PH}/G_{IAVE} = G_{PC}/G_{IAVE}$
"Eye-Balls-In"	- Deceleration direction proceeding from chest to back caused by a force vector from back to chest
"Eye-Balls-Out"	- Deceleration direction proceeding from back to chest caused by a force vector from chest to back
FIN.	- Measurement after drop was completed (inches)
G	- Ratio of decelerative force to the acceleration of gravity - $G = a/32.2$
G_{IAVE}	- Average or plateau measurement of recorded decelerations of carriage impact surface
G_{ON}	- Deceleration Onset Rate or Force Application Rate is the rate at which the force is applied to the couch occupant $G_{ON} = G_{PH}/\text{Rise Time} = G_{PC}/\text{Rise Time (G's/Sec)}$
G_{PC}	- Peak decelerations recorded on dummies chest
G_{PH}	- Peak decelerations recorded on dummies head
High Energy Drop	- 30 ft/sec impact velocity
INI.	- Initial measurement before drop (inches)
Low Energy Drop	- 13.9 ft/sec impact velocity
PER.	- Permanent stretch or elongation of net fabrics (inches)
Rise Time	- Time from when G-t curve leaves zero and reaches the maximum point (seconds)
t	- Time (seconds)

INTRODUCTION

Present body support systems such as used in conventional aircraft are impractical for spacecraft because of weight and comfort considerations, and are not designed for proper load distribution for the high accelerations of boost or reentry. In recent years, advances in body support systems that provide the proper load distribution to the seat occupant have been made and are incorporated in the Mercury couch concept, which is an individual contoured solid body support. However, this concept is still basically heavy, cumbersome, and uncomfortable. For these reasons a body support study and development program was initiated by the Crew Systems Division. The design objectives of this development program are a body support and restraint system that provides a universal fit, and is lightweight, economical, energy absorbent, adjustable and stowable.

An investigation and evaluation of existing support systems was made. As a result of this evaluation, the net support concept was selected for development because it demonstrated the best possibility of providing the previously mentioned design objectives. The first phase of development reported herein concerns fabric tests for determination of the near-optimum net type fabric to be used. Fabric materials selected to be tested were Nylon and Dacron Raschel netting, because of the strength properties of these materials, and Somyk loop netting, because of its load attenuation capability.

Full body supports using the above-mentioned netting type fabrics, and couch frameworks were designed and constructed. Drop tower tests were conducted with impact velocities of 13.9 ft/sec and 30 ft/sec. Various deceleration forces were simulated by varying the cross-sectional area of the aluminum honeycomb, used as an energy absorber at the impact surface of the dropping carriage. Transverse decelerations were measured at the tower carriage impact surface and at the approximate center of gravity of the couch frame, the dummy head, and the dummy chest. Motion pictures of the test specimen at impact were taken at 400 frames per second for each drop.

TEST EQUIPMENT

The general arrangement of the lower impact portion of the drop tower facility is shown in figure 1. The drop tower has the capability of a maximum impact velocity of 36 ft/sec and carriage induced loads of 60 to 110g's, dependent on payload weight. These conditions are simulated using $\frac{1}{4}$ -3003-.001N aluminum honeycomb for energy absorption.

To measure the dynamic forces from the onset of impact until shortly after impact, C.E.C. accelerometers of the Four-Active Arm Strain Gage type are used. These accelerometers were used in conjunction with wide-band and/or carrier amplifiers. The outputs of these amplifiers are passed through low-pass filters to limit the frequency response to 130 cps as determined by preliminary tests to be a practical cutoff point. The wave forms were then recorded using C.E.C. Type 5-114 oscillographs.

The net couch framework which was used during these tests is indicated in figure 2. This framework was constructed from $\frac{3}{4}$ O.D. \times 0.12 Wall, 4130 steel tubing, heat treated to a Rockwell C-42 condition, to withstand the stresses induced from a 100g decelerative impact.

The particular knitting patterns used in knitting the net fabric used throughout these tests is indicated in figures 3a and 3b. Nylon and Dacron Raschel net was knitted to the specifications of Mil. Spec. No. C-8061 (USAF). The Somyk fabric was knitted in a loop pattern designed to distribute the non-uniform load and produce permanent stretching of the material with resulting load attenuation starting at approximately the 12-16g level.

The anthropometric dummy used during these tests resting upon three different types of Somyk torso supports is shown in figures 4a, 4b, and 4c. A torso and head support made with 4 inches of Somyk fabric on each side of the head is indicated in figure 4a. The middle portion of the support was composed of Nylon Raschel net. To reduce the neck snap found to exist in this support, an additional amount of Somyk fabric was added at the head portion of the torso and head support as shown in figure 4b. A total Somyk fabric body support is indicated in figure 4c. The leg and thigh supports used with all of these body supports were composed of 4 inches of Somyk fabric attached at each side of the Nylon Raschel net-frame. The three body support types indicated in figures 4a, 4b, and 4c will be referred to subsequently as Somyk 1, 2, and 3, respectively. The Somyk fabric used in these tests was knitted in three variations of strength and was assembled dependent upon the weights of the head and neck, torso and buttocks, and thighs and legs. It is understood that when inducing energy absorption by the permanent stretch of Somyk loop fabric, a one-shot type body support is introduced, but the use of this type support would still meet all the design objectives mentioned previously.

Motion pictures were taken with a Miliken camera at 400 frames/second of all drops.

The general assembly employed throughout this test program is shown in figure 5.

Netting type body supports were laced to a tubular framework, and the couch-dummy assembly was attached to the tower carriage.

TEST PROCEDURES

Throughout all the drops with body supports knitted from Nylon and Dacron Raschel netting, there were decelerations of approximately 4, 6, 8, 10, and 12g's induced at the impact surface. During the drops when Somyk loop netting was used, the induced forces were 4, 8, 12, 16, and 30g's. This change in induced forces was made to obtain higher loads at the impact surface to determine the attenuation capability of Somyk fabric. When the low energy drops were completed the impact velocity was increased from 13.9 ft/sec to 30 ft/sec. This increase in impact velocity increased the energy level by approximately a factor of 4.

During the low energy Dacron and Nylon Raschel drops the dummy was restrained as shown in figure 6a. This type zipper restraint was accomplished by sewing zippers directly on the net and sewing the mating side of the zippers to a pair of flight coveralls.

When Somyk material was used, the restraint system shown in figures 4a, 4b, and 4c was chosen. This system was used to preclude fabric rupture from the metal zipper during permanent elongation of the Somyk fabric. A 500 pound test Nylon cord was used and was tied to the net at the high and low points where the zipper was used on previous drops. For the greater velocity high energy drops, the restraint system shown in figure 6b was used.

The general setup and restraint system used to test the Mercury torso support is shown in figure 6c. This system consists of high strength Nylon webbing chest and lap strap, with the feet tied to the wooden framework with 500 pound test Nylon cord.

Vertical accelerations were recorded at the four locations as previously mentioned, permanent body displacement measurements were taken when testing Somyk fabric and are presented in table I; dynamic response factors were calculated between the impact surface, dummy head, and chest are shown in table II. Force application rates between the dummy and the various net supports were calculated and are presented in table III.

PRESENTATION AND DISCUSSION OF DATA

Comparisons of impact loads measured on a dummy's head and chest when using Nylon, Dacron, and Somyk-3 net type body supports under low and high energy inputs and different induced loads, are presented in figures 7 to 10. It can be seen from an inspection of figure 7a that the Dacron material produces approximately 40 percent higher "Eye-Ball-In" decelerations and faster force application rates on the dummy's head than either Nylon or Somyk-3 material. Although the "Eye-Balls-Out" accelerations of the dummy's head when using Dacron material is 50 percent less than with Nylon material, it is also 80 percent more with Somyk-3 fabric. Figure 8b presents the impact loadtime analysis curves measured in the dummy's chest. The significant point here is that when using a Somyk-3 body support, the "Eye-Balls-In" acceleration transmitted to the dummy is an average of 8 percent lower than with the Nylon and Dacron material.

Figure 8 presents the same type of analysis as figure 7 when using the three different configurations of Somyk body supports, shown in figures 4a, 4b, and 4c. The acceleration portion of the figure shows that Somyk-3 imparts 28 percent less "Eye-Balls-In" decelerations than Somyk-1, and 26 percent less than Somyk-2. The total duration of the "Eye-Balls-Out" accelerations caused by rebound above the original position is minimal when using Somyk-3.

Figure 8b shows generally the same type of analysis of the dummy's chest measurements with much lower magnitudes in difference between Somyk fabric configurations.

The impact loads imparted to the dummy's head by the various net body supports under high energy and high induced load conditions are presented in figures 9 and 10. There are no chest loads presented because during these tests the dummy's buttocks was seen to bottom onto the couch frame structure, therefore, affecting the chest accelerometer and causing very high accelerations to be recorded.

Figure 9 shows the same "Eye-Balls-In" accelerations imparted to the dummy's head by both Nylon Raschel and Somyk-3 fabrics. The duration of total acceleration is longer when using Somyk-3.

Figure 10 provides comparison of impact loads imparted to the dummy's head by the three configurations of Somyk fabric. Although here it can be seen that Somyk-3 imparts approximately 10 percent more acceleration to the dummy's head, it is of a lower rate and a short time duration longer.

Figure 11 presents a comparison of acceleration time curves recorded at the four accelerometer locations for the various induced loads during the low energy drop tests using Nylon Raschel body supports. An analysis of these figures show that regardless of induced loads, to the maximum of these tests, Nylon Raschel net imparts approximately 16g's to the head and chest. In all cases the head accelerations rapidly change from 16g "Eye-Balls-In" to 8g "Eye Balls Out". This reversal of acceleration is caused by rebound from maximum displacement above dummies' (original) head position. This rapid reversal of position caused by the reversal snaps the neck and would probably result in injury to an occupant's neck and head.

Comparisons of impact loads measured on a dummy's chest and head at various induced loads during the low energy drop test using Dacron Raschel material for the body support are presented in figure 12. A comparison of these figures again shows that regardless of induced forces, to the extent covered in this test program, Dacron material induces about the same forces to the dummy's chest as Nylon Raschel and imparts approximately 40 percent more accelerations to the head than Nylon Raschel net. Although the "Eye-Balls-Out" accelerations caused by rebound above the dummies' original position is approximately 25 percent less than those produced by Nylon Raschel, these "Eye-Balls-Out" accelerations result in a neck snapping problem. The larger "Eye-Balls-in" accelerations are due to Dacron material not elastically stretching as far as Nylon. The lower "Eye-Balls-Out" accelerations are probably caused by Dacron material taking a permanent set or reaching its elastic limit faster than Nylon. Figure 13 presents acceleration-time histories measured at various induced loads when using Somyk-1 as a body support. From an inspection of these figures, it can be seen that the loads imparted to the dummy are dependent upon the induced loads. Up to 16g, the loads transmitted to the dummy increase as the induced load increases, at this point the imparted load remains the same or less. At a 30g induced load, (fig. 13e), the head and chest accelerations were recorded at approximately 16g's, a reduction of 40 percent with the Somyk-1 body support. Acceleration-time histories measured at the four accelerometer locations under various induced loads using Somyk-2 net body support are shown in figure 14. A comparison of the curves for Somyk-2 show the same typical trend as Somyk-1 except the imparted accelerations to the head and chest are 5 to 10 percent lower with Somyk-2.

Figure 15 presents acceleration-time curves measured at various accelerometer locations using Somyk-3 as a body support. An inspection of these curves indicate that when using Somyk-3 as a body support, there is a large similarity between the head and chest curves. Usually the two curves are shifted, but the peak and duration of accelerations are

generally the same. The head and chest curves show a very limited amount of "Eye-Balls-Out" acceleration caused by rebound above the original position. With the use of Somyk-1 and Somyk-2, these "Eye-Balls-Out" accelerations are produced in the head. The "Eye-Balls-Out" accelerations and the similarity of the head and chest curves show that Somyk-3 net fabric limits rebound above the original position and reduces the neck snap to a tolerable amount. The curves also show a tendency for 5 to 10 percent less load being imparted to the dummy, up to 16g induced load, than with the use of either Somyk-1 or Somyk-2 fabrics. The 30g induced load drop (fig. 16e) shows the same trend (40 percent reduction of g), as Somyk-1 and Somyk-2. Although Somyk-3 does not show a sizable reduction of imparted g's over and above Somyk-1 and Somyk-2, it should be pointed out that the same load was applied to all three Somyk nets and the area attenuating the load was larger with the Somyk-3 fabric. If the load-Somyk area-ratio was the same for all three configurations, there would be quite an improvement in load attenuation of Somyk-3.

Figure 16 presents acceleration-time histories measured at various accelerometer locations using Somyk-1, Somyk-2, Somyk-3, and Nylon Raschel body supports with approximately 20g's induced at the impact surface of the carriage and an impact velocity of 30 ft/sec. The chest curves in these figures go off scale at the top of the page because of the buttocks bottoming onto the couch frame structure. This bottoming would affect the chest accelerometer. Inspection of these figures shows very little difference between Somyk-1, Somyk-2, and Somyk-3. Somyk-3 tends to enlarge the duration of total accelerations. Again, it is felt that if the induced load-Somyk area-ratio were the same, Somyk-3 would have shown at least a 50 percent load attenuation factor. A comparison between figures 16a, 16b, 16c, and 16d indicate that with Nylon Raschel net, a faster loading action is taking place, this causing more rebound above the original position and more violent neck snapping.

Acceleration-time histories measured on an anthropometric dummy when using a Mercury type torso support are presented on figures 17 and 18. An inspection of these figures show that this type of body support has no "built-in" attenuation capability. The response of the dummy shows an increase of 100 to 300 percent in g over the inputs to the carriage. A rapid and continued reversal in measured accelerations also occurs. The amount and rapidity of this reversal is dependent on the induced loads on the tower carriage.

Somyk fabric permanent stretch is shown in figure 19 and tabulated in table I. From an inspection of the photographs in figure 19, it can be seen that Somyk-1 and Somyk-2 have a capability of stretching under dynamic loading and absorbing energy. Again, because of the load-Somyk

area-rates, no permanent stretch except under the head was observed, although permanent tightening of the knitting pattern occurred. Table I shows permanent stretch of 1.25 and 3.25 inches under various parts of the body.

Comparison of the Dynamics Response Factors between the loads induced at the impact surface of the carriage and those imparted to the dummy by the different net materials is presented in figure 20 and table II. In table II it can be seen that with all net materials tested, the dynamic response factor decreases as the induced load increases. Inspection of table II shows that Nylon netting produces dynamic response from 4.17 to 1.38 on the dummy's head and 4.05 to 1.59 in the chest area; Dacron material produces factors of 3.67 to 2.14 on the head and 2.66 to 1.58 in the chest area; Somyk-1 factors are 1.55 to 0.61 in the head area and 2.1 to 0.63 in the chest area; Somyk-2 factors are 2.12 to 0.57 on the head and 1.8 to 0.56 in the chest area; Somyk-3 response factors are 2.0 to 0.64 in the head and 2.13 to 0.59 in the chest area. Any dynamic response factors below 1 indicates the net material is demonstrating load attenuation and energy absorption. The calculated factors show that all Somyk fabric configurations provide load attenuation of the magnitude of 40 to 50 percent with higher induced loads. Nylon and Dacron net material increase the loads imparted to the dummy from 300 to 400 percent. For low impact forces, all Somyk fabric configurations tend to increase the loads slightly. This increase in dummy response over and above the low input loads occurs because the Somyk fabric is designed not to yield until after an input of 12 to 16 g's is reached.

The application rates of forces imparted to the dummies' head and chest by the various materials is presented in table III. These application rates were calculated by using peak g and rise time. It can be seen from table III that Dacron net imparts the highest application rates of the three materials. The Somyk configurations generally impart the lowest application rates. The application rates with all materials usually tend to increase to the point that permanent stretch begins, then fall off until the maximum permanent stretch is reached.

CONCLUDING REMARKS

Studies (ref. 1 and 2) have been made by the Aeronautical Systems Division, Wright-Patterson Air Force Base on the comfort and sustained acceleration properties of the net seat concept. Both of these studies indicate that the net seat concept of body support is very feasible considering the above-mentioned areas.

To determine the feasibility of netting type fabrics for use as crew couches under impact type accelerations, drop tests were conducted using couches fabricated from Nylon Raschel net, Dacron Raschel net, and Somyk loop fabric. Because of the previous knowledge of the rebound and neck snapping problems of Nylon and Dacron Raschel netting, these tests were slanted toward the determination of the feasibility of Somyk loop fabric to reduce and/or eliminate these problems. Tests conducted with a Mercury torso support were used as control data.

The drop test and data analysis have demonstrated that Somyk-3 (total body support fabricated from Somyk cord) will limit the rebound above the couch occupants original position, provide the capability to allow the head and torso to travel into the net in the same plane (which minimizes the neck snapping problem) and attenuate the impact loads and absorb energy by permanent elongation and mechanical friction.

Somyk-3 fabric could fulfill the previously mentioned designed objectives, with proper design of couch framework. Based on this study, the development of a universal, energy-absorbing, net couch and restraint system using Somyk-3 type fabric is being continued. A torso support capable of being used in the Mercury spacecraft is under development and will be reported on in a separate working paper.

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TABLE I. - PERMANENT STRETCH OF SOMYK FABRIC

Test No.	Head			Shoulder			Hip			Leg		
	INI.	FIN.	PER.	INI.	FIN.	PER.	INI.	FIN.	PER.	INI.	FIN.	PER.
** 9 (Nylon)	7.5	7.0	0.5	6.5	5.5	1.0	8.0	6.5	1.5	22.5	22.5	0
** 8 (Somyk No. 3)	7.0	5.75	1.25	5.75	4.5	1.25	6.75	5.5	1.25	21.5	21.0	.50
** 7 (Somyk No. 2)	7.5	4.5	3.0	6.25	3.0	3.25	7.5	4.5	3.0	21.5	20.25	1.25
** 6 (Somyk No. 1)	13.5	11.75	.75	6.0	3.25	2.75	7.5	5.0	2.5	21.75	20.5	1.25
* 5 (Somyk No. 3)	15.25	13.88	1.37	11.0	9.88	1.12	7.0	5.5	1.5	20.88	20.0	.88
* 4 (Somyk No. 2)	15.0	12.75	2.25	11.5	9.25	2.25	8.0	6.0	2.0	21.5	20.75	.75
* 3 (Somyk No. 1)	14.5	12.75	1.75	11.0	9.25	1.75	7.25	6.0	1.25	21.5	20.75	.75

* Low Energy Drop

** High Energy Drop

TABLE II.- DYNAMIC RESPONSE FACTORS BETWEEN CARRIAGE IMPACT SURFACE AND DUMMY

TEST	DROP	MATERIAL	G _{LAVE}	IMPACT VEL	G _{PH}	DRF	G _{PC}	DRF
1 ↓	1	Nylon ↓	4	13.9	16.7	4.17	16.2	4.05
	2		6	13.9	14.7	2.45	15.8	2.63
	3		8	13.9	13.2	1.65	17.8	2.22
	4		9	13.9	14	1.56	16.2	1.80
	5		11	13.9	15.2	1.38	17.5	1.59
2 ↓	1	Dacron ↓	6	13.9	22.	3.67	15.	2.66
	2		6	13.9	27.	4.5	16.2	2.7
	3		7.5	13.9	24.	3.2	16.8	2.24
	4		9.5	13.9	21.8	2.29	16.8	1.77
	5		10.5	13.9	22.4	2.14	16.6	1.58
3 ↓	1	Somyk 1 ↓	4.	13.9	6.2	1.55	8.4	2.1
	2		8.5	13.9	16.	1.88	15.2	1.79
	3		11.	13.9	21.1	1.92	18	1.64
	4		16.4	13.9	16.4	1.00	14.2	.86
	5		27	13.9	16.4	.61	17.	.63
4	1	Somyk 2	--	--	--	---	---	---

TABLE II.- DYNAMIC RESPONSE FACTORS BETWEEN CARRIAGE IMPACT SURFACE AND DUMMY - Concluded

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TIME	DROP	MATERIAL	G _{LAVE}	IMPACT VEL	G _{PH}	DRF	G _{PC}	DRF
↓ 5	2	↓ Somyk 3	8	13.9	17	2.12	14.4	1.8
	3		12	13.9	19.4	1.62	16.4	1.36
	4		16.5	13.9	16.	.97	15.5	.94
	5		29.5	13.9	16.3	.57	16.6	.56
	1		4	13.9	8.	2.	8.5	2.13
↓ 6	2	↓ Somyk 1	8.5	13.9	14.6	1.72	14.8	1.74
	3		10.5	13.9	17.6	1.68	16.	1.52
	4		14.	13.9	15.	1.07	15.	1.07
	5		25.	13.9	16.	.64	14.7	.59
	1		18.	30.	24.4	1.35	----	----
7	1	Somyk 2	18.	30.	24.3	1.35	----	----
8	1	Somyk 3	18.	30.	27.7	1.54	----	----
9	1	Nylon	20.	30.	27.5	1.38	----	----

TABLE III.- FORCE APPLICATION RATE BETWEEN DUMMY AND VARIOUS NET MATERIALS

TEST	DROP	IMPACT VELOCITY	MATERIAL	G _{PH}	RISE TIME	G _{ON}	G _{PC}	RISE TIME	G _{ON}
1	1	13.9 ↓	N ↓	16.7	.028	600	16.2	.061	265
	2			14.7	.020	734	15.8	.051	310
	3			13.2	.024	550	17.8	.063	283
	4			14.	.023	608	16.2	.050	324
	5			15.2	.056	271	17.5	.062	283
2	1		D ↓	22.	.021	1048	15	.072	208
	2			27.	.022	1228	16.2	.059	275
	3			24.	.025	960	16.8	.059	285
	4			21.8	.021	1040	16.8	.07	240
	5			22.4	.021	1070	16.6	.048	346
3	1		S-1 ↓	6.2	.040	155	8.4	.090	93
	2			16.	.037	433	15.2	.060	253
	3			21.2	.030	707	18.	.045	400
	4			16.4	.035	469	14.2	.037	383
	5			16.4	.029	565	17.	.028	607
4	1		S-2	--	--	---	---	---	---

TABLE III.- FORCE APPLICATION RATE BETWEEN DUMMY AND VARIOUS NET MATERIALS - Concluded

TEST	DROP	IMPACT VELOCITY	MATERIAL	G _{PH}	RISE TIME	G _{ON}	G _{PC}	RISE TIME	G _{ON}
5	2	13.9	S-2	17.	.030	566	14.4	050	288
	3	↓	↓	19.4	.024	808	16.4	037	443
	4	↓	↓	16.	.030	533	15.5	045	348
	5	↓	↓	16.3	.029	562	16.6	049	339
	1	↓	S-3	8.	.048	167	8.5	085	100
	2	↓	↓	14.6	.038	384	14.8	056	264
	3	↓	↓	17.6	.029	608	16.	051	314
	4	↓	↓	15.	.035	428	15.	045	333
	5	↓	↓	16.	.036	444	14.7	04	368
6	1	30.	S-1	14.4	.045	542	-----	-----	-----
7	1	30.	S-2	24.3	.050	486	-----	-----	-----
8	1	30.	S-3	27.7	.059	470	-----	-----	-----
9	1	30.	N	27.5	.042	656	-----	-----	-----

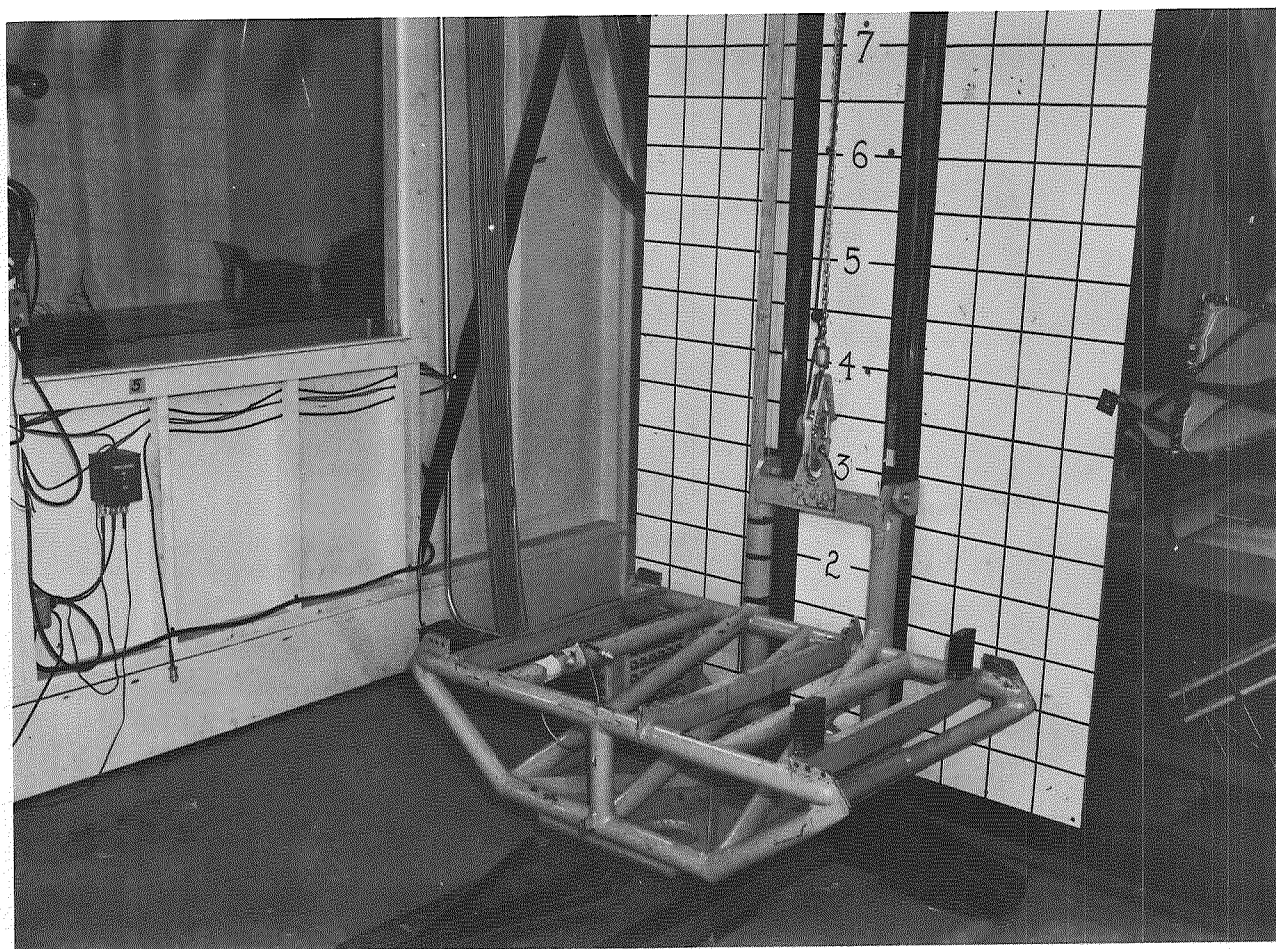


Figure 1.- Drop tower facility

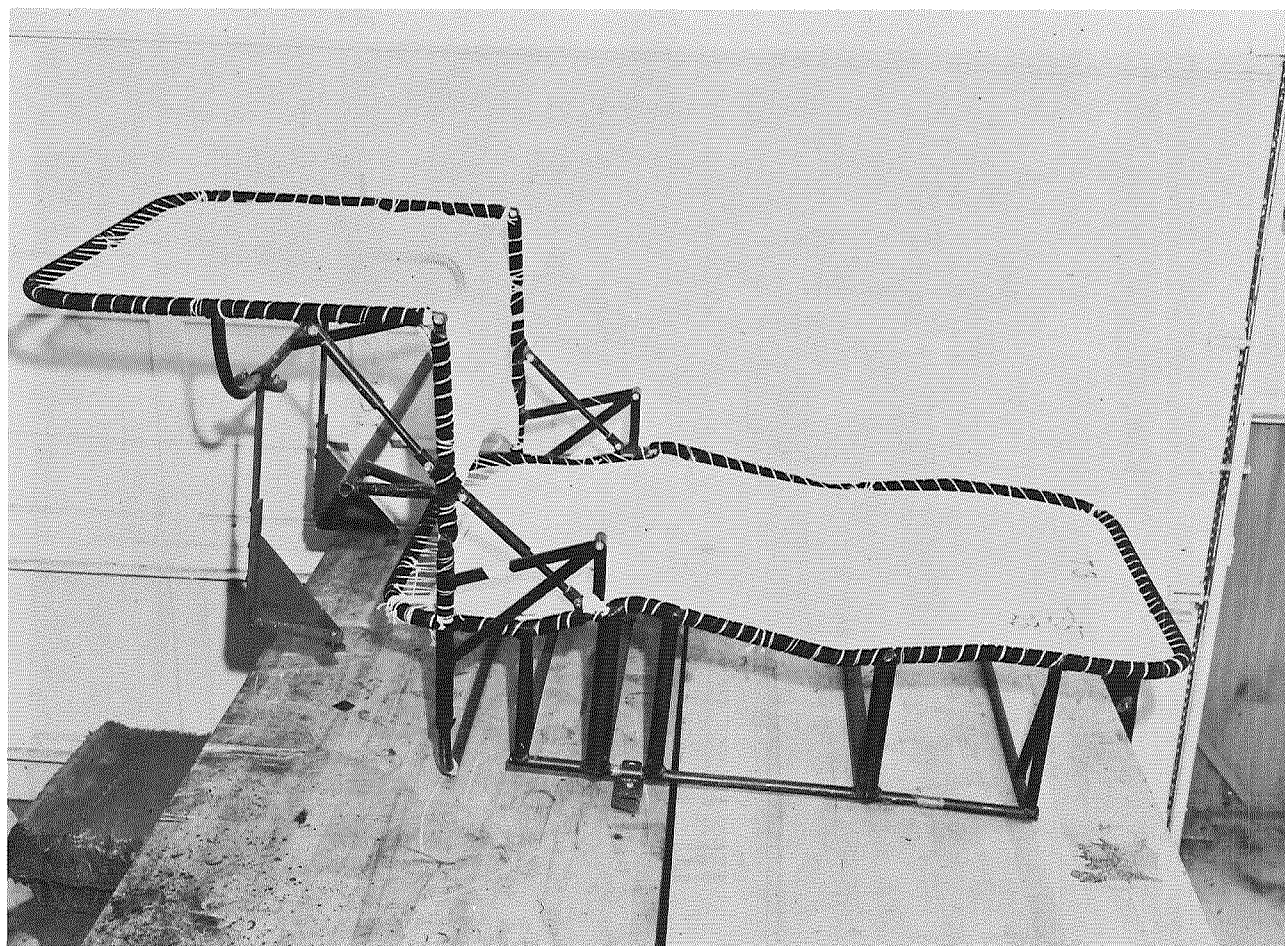
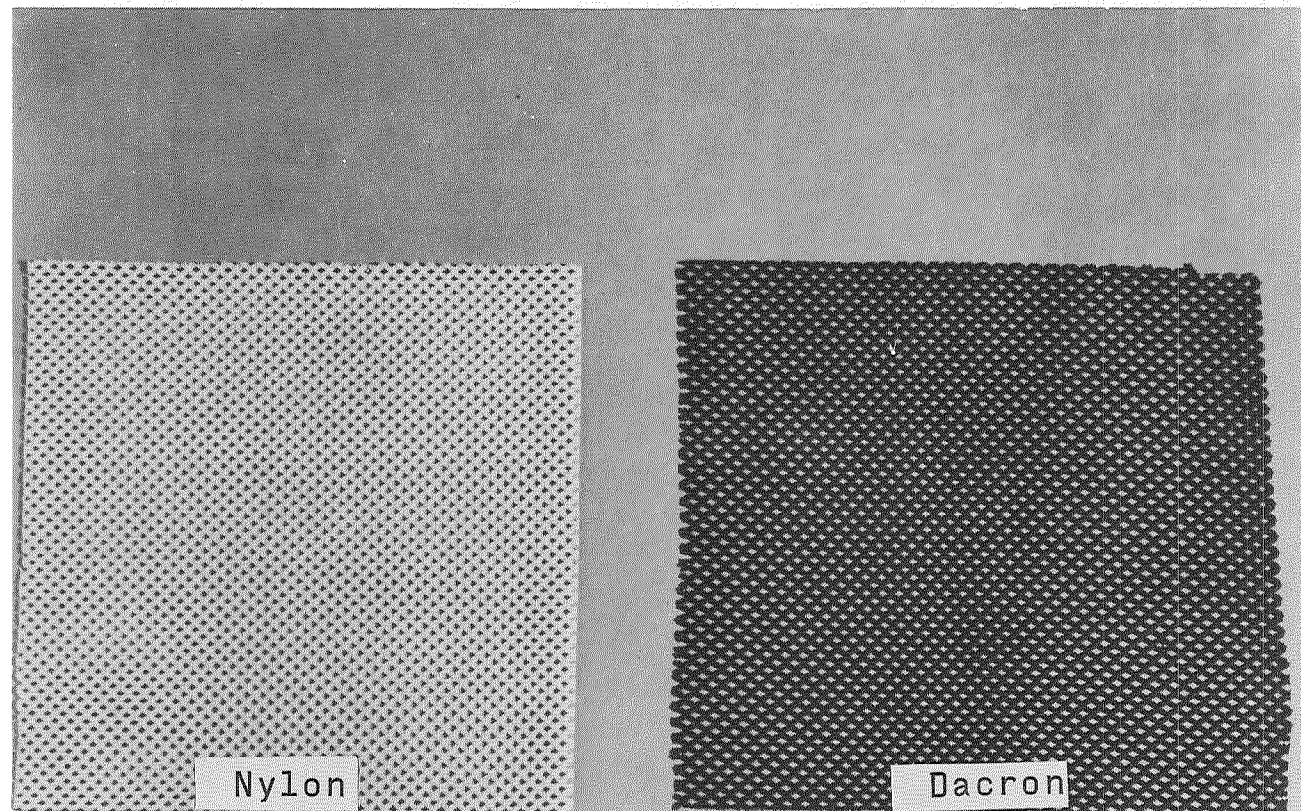
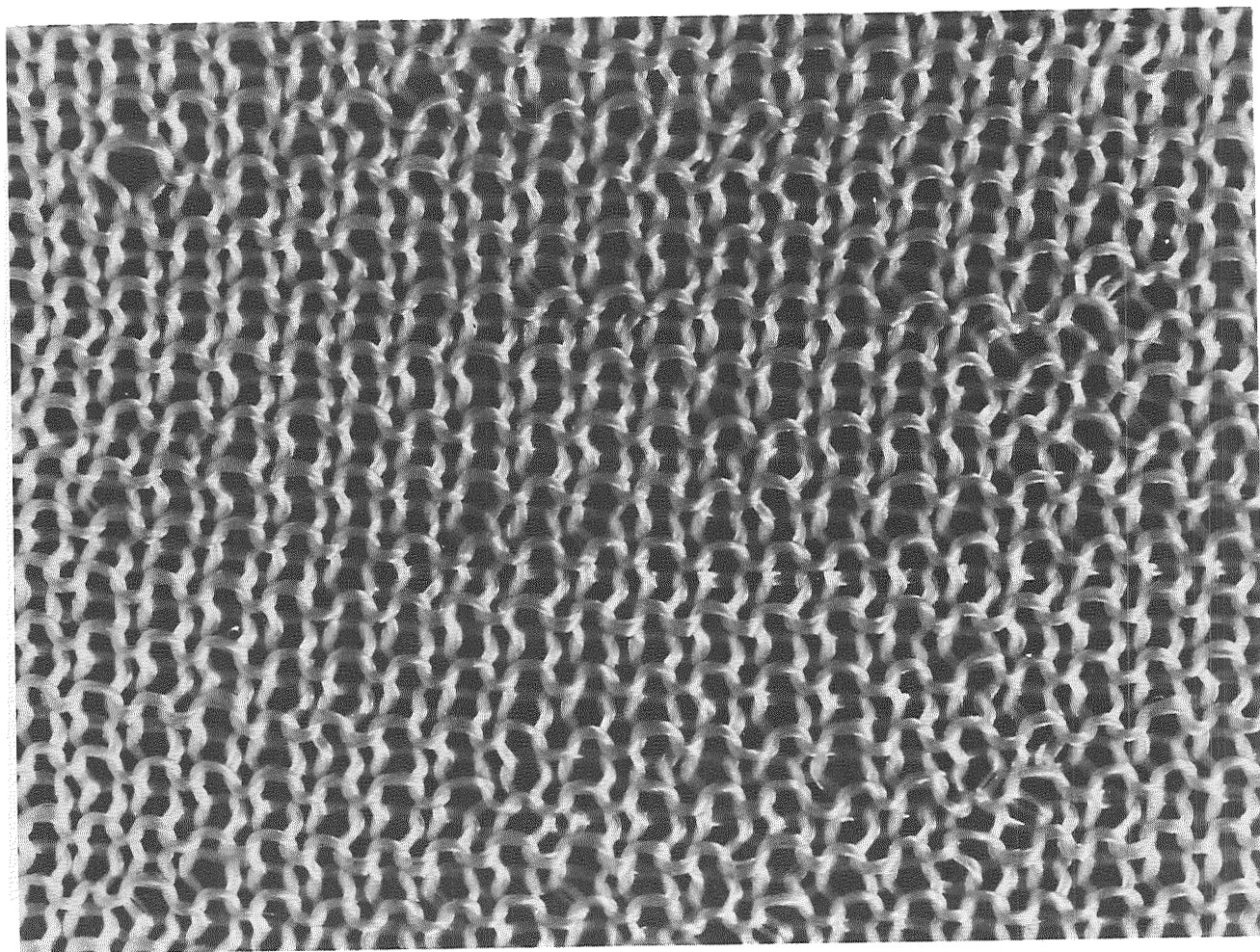


Figure 2.- Net couch frame.



(a) Raschel

Figure 3.- Selected net patterns.



(b) Somyk

Figure 3.- Concluded.



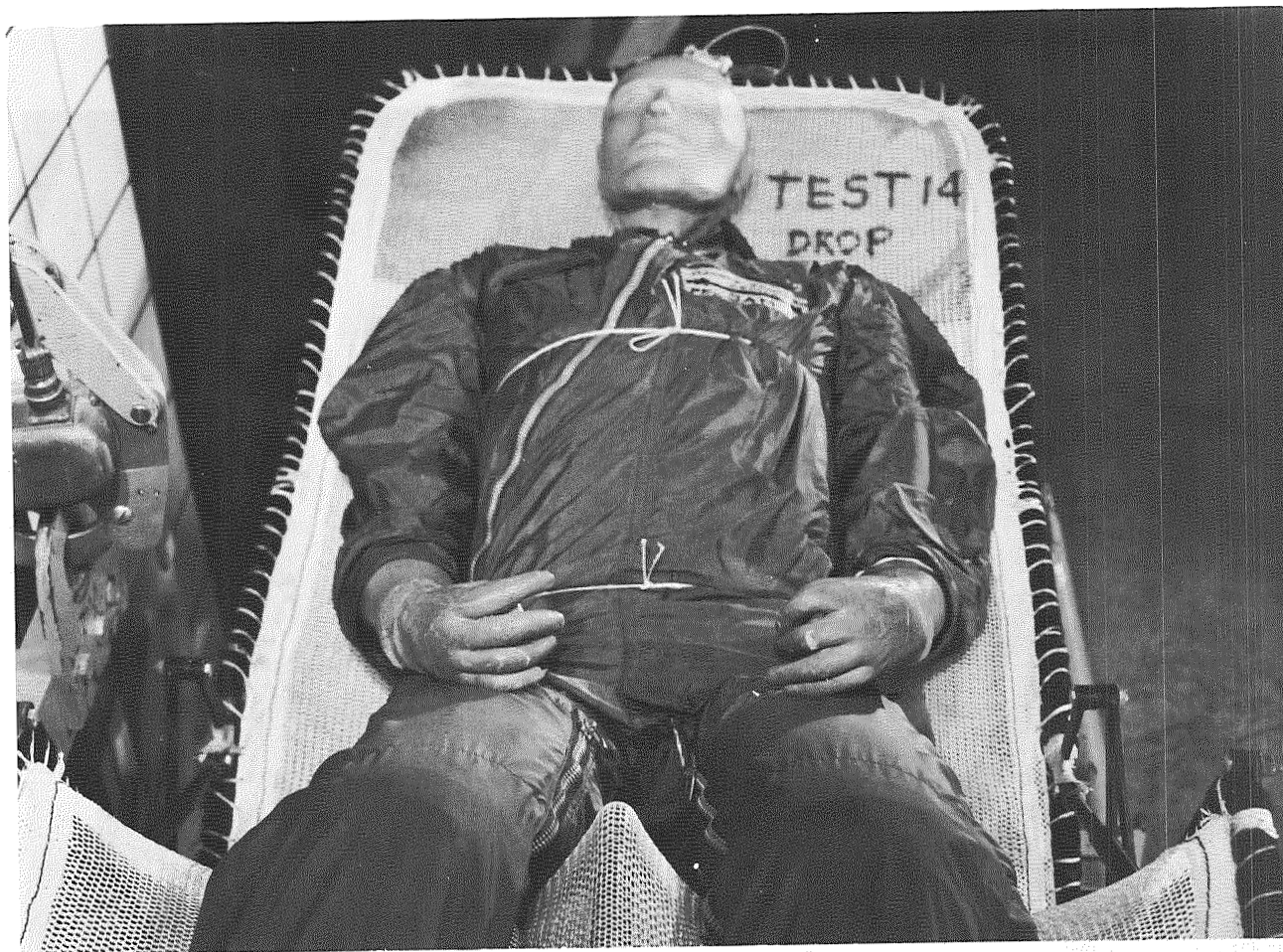
(a) Somyk type 1

Figure 4.- Three types Somyk torso supports.



(b) Somyk type 2

Figure 4.- Continued.



(c) Somyk type 3

Figure 4.- Concluded.

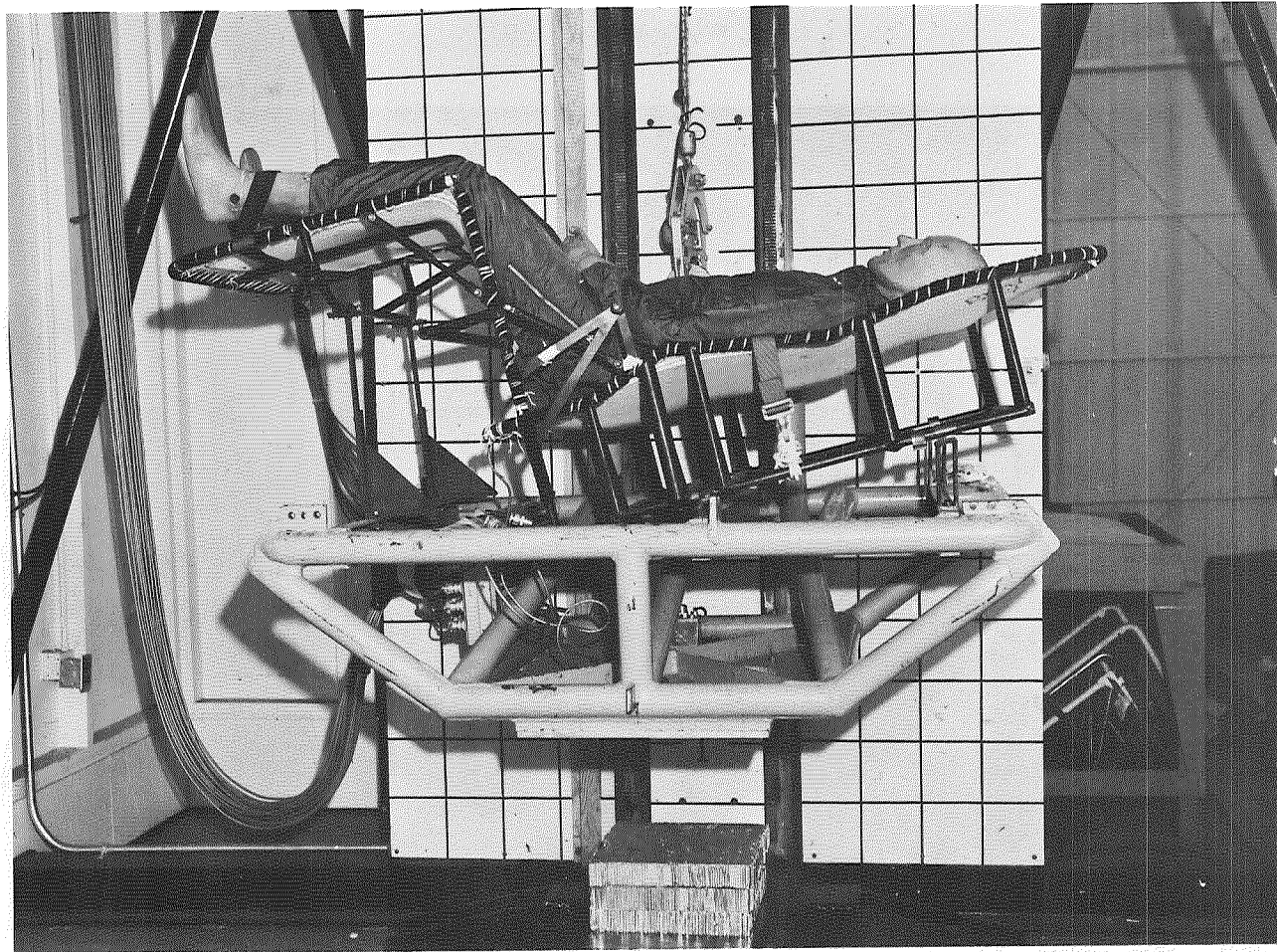
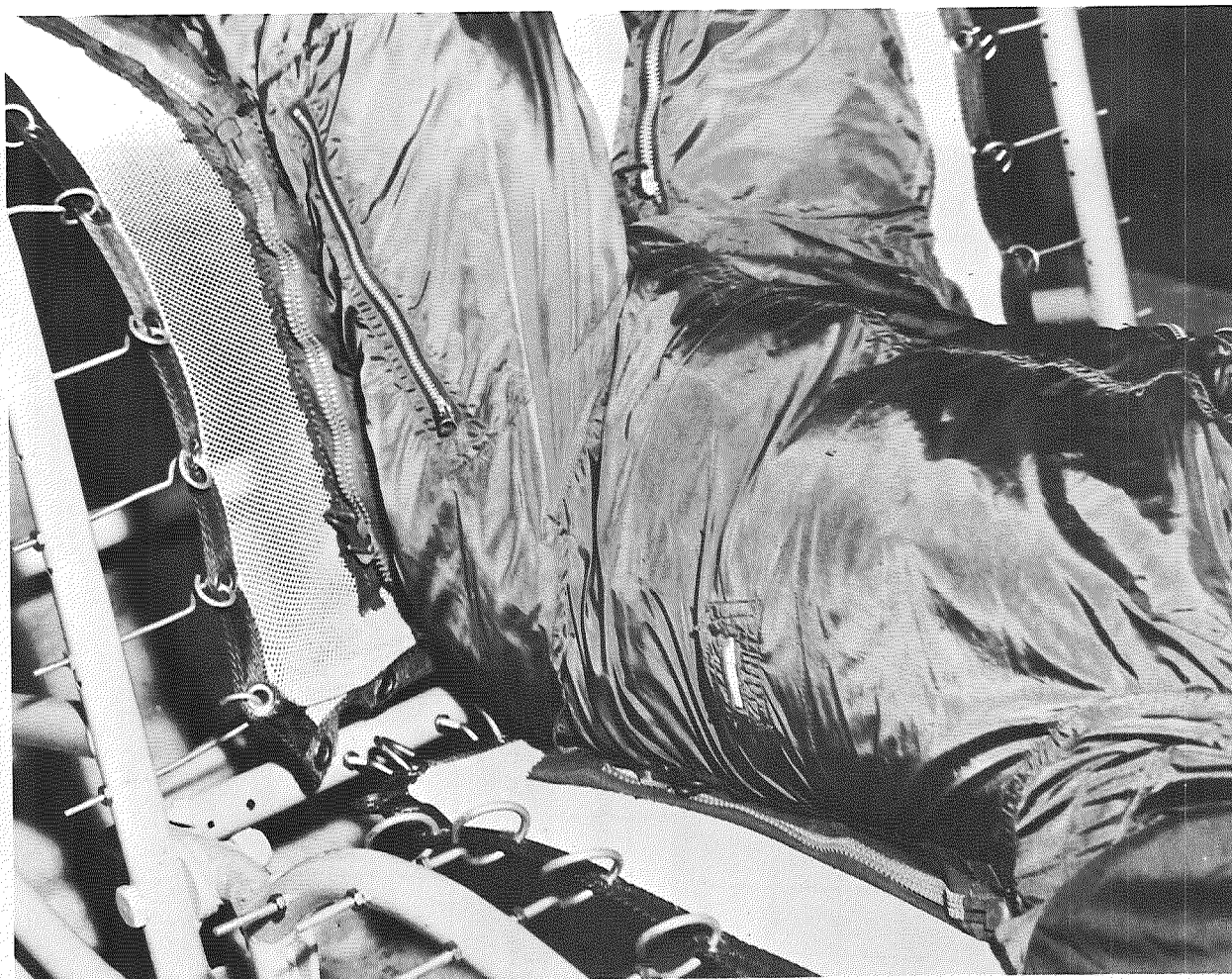
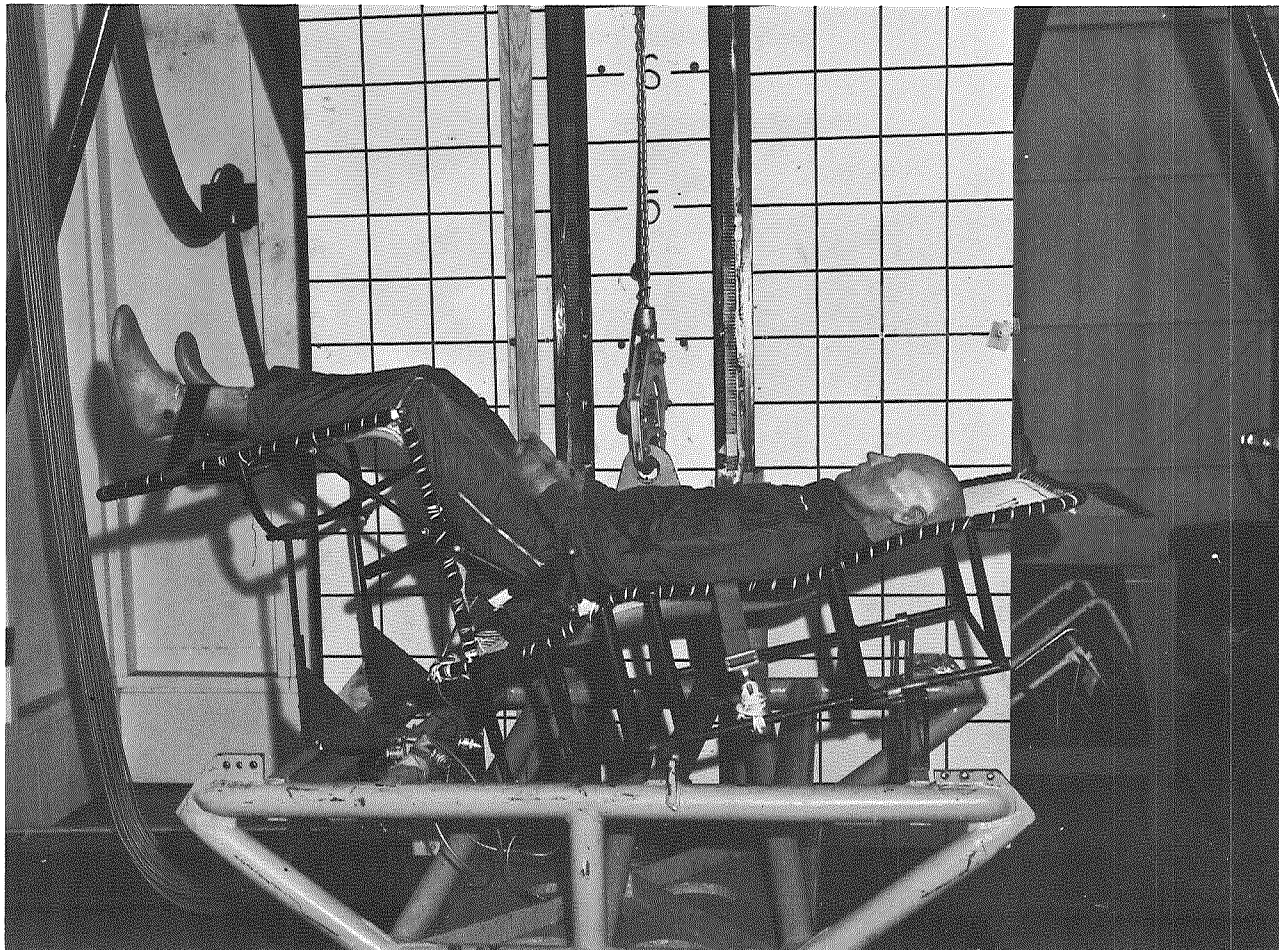


Figure 5.- Carriage-couch-dummy assembly.



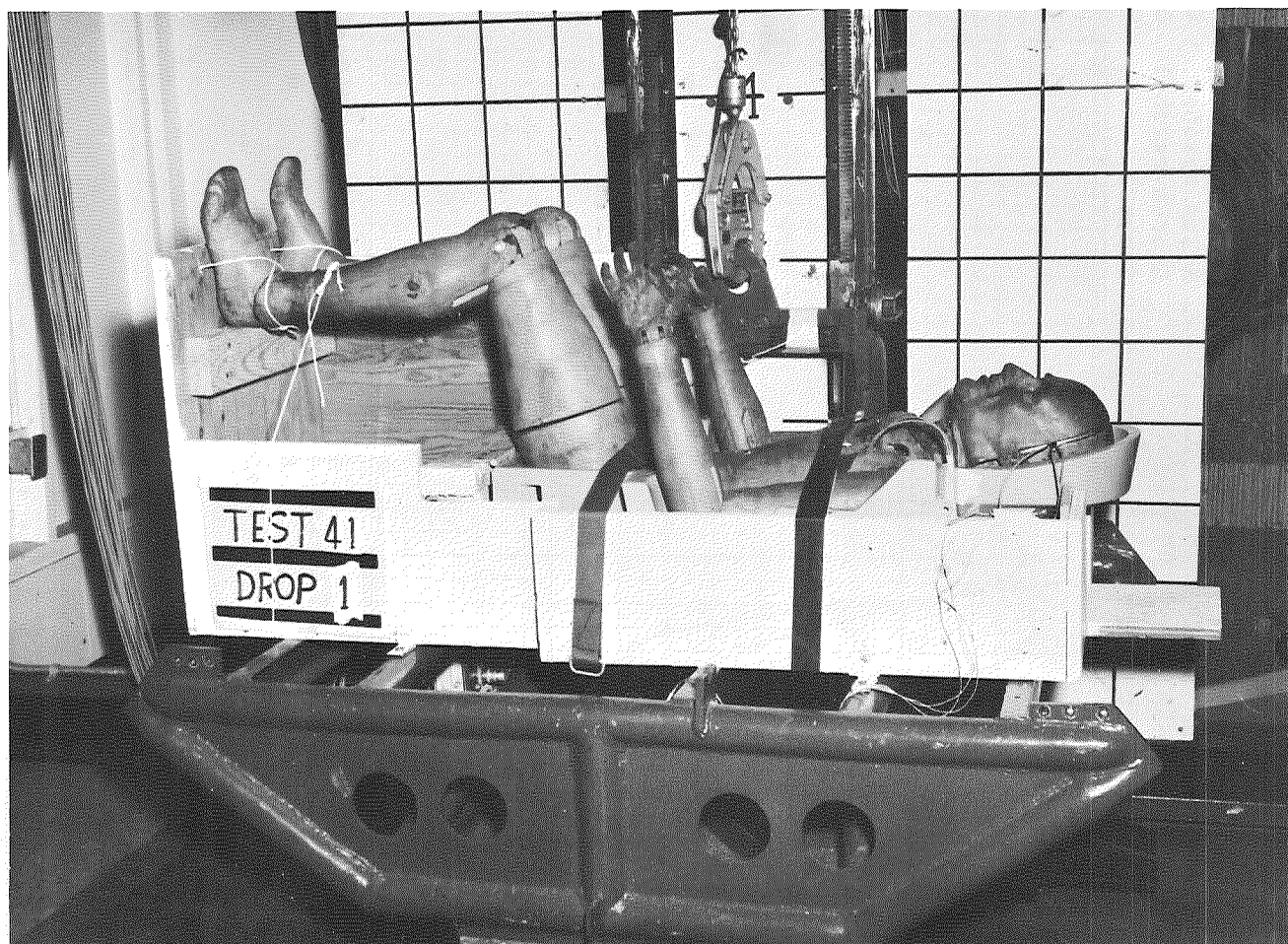
(a) Low energy drop

Figure 6.- Restraint system.



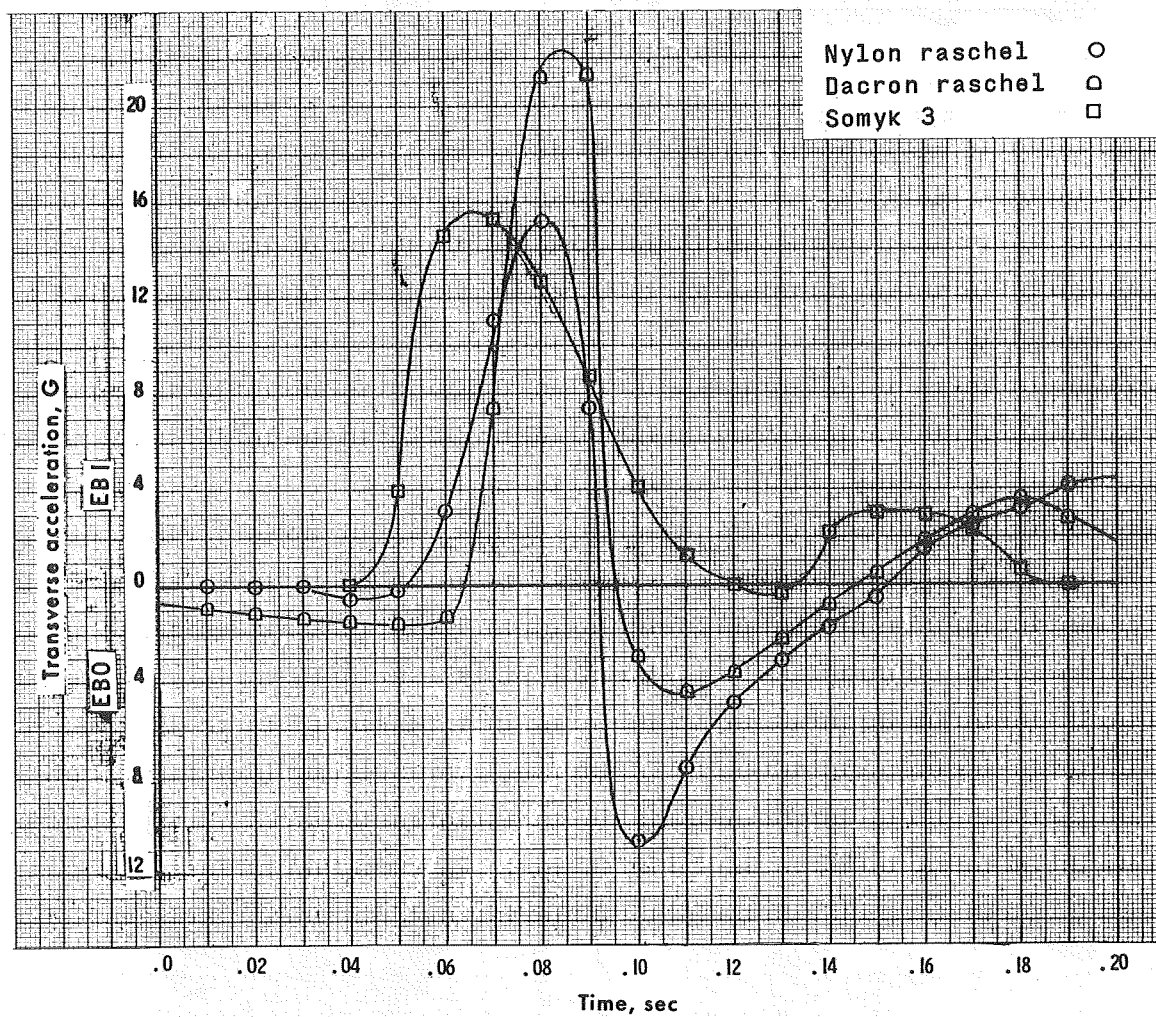
(b) High energy drop

Figure 6.- Continued.



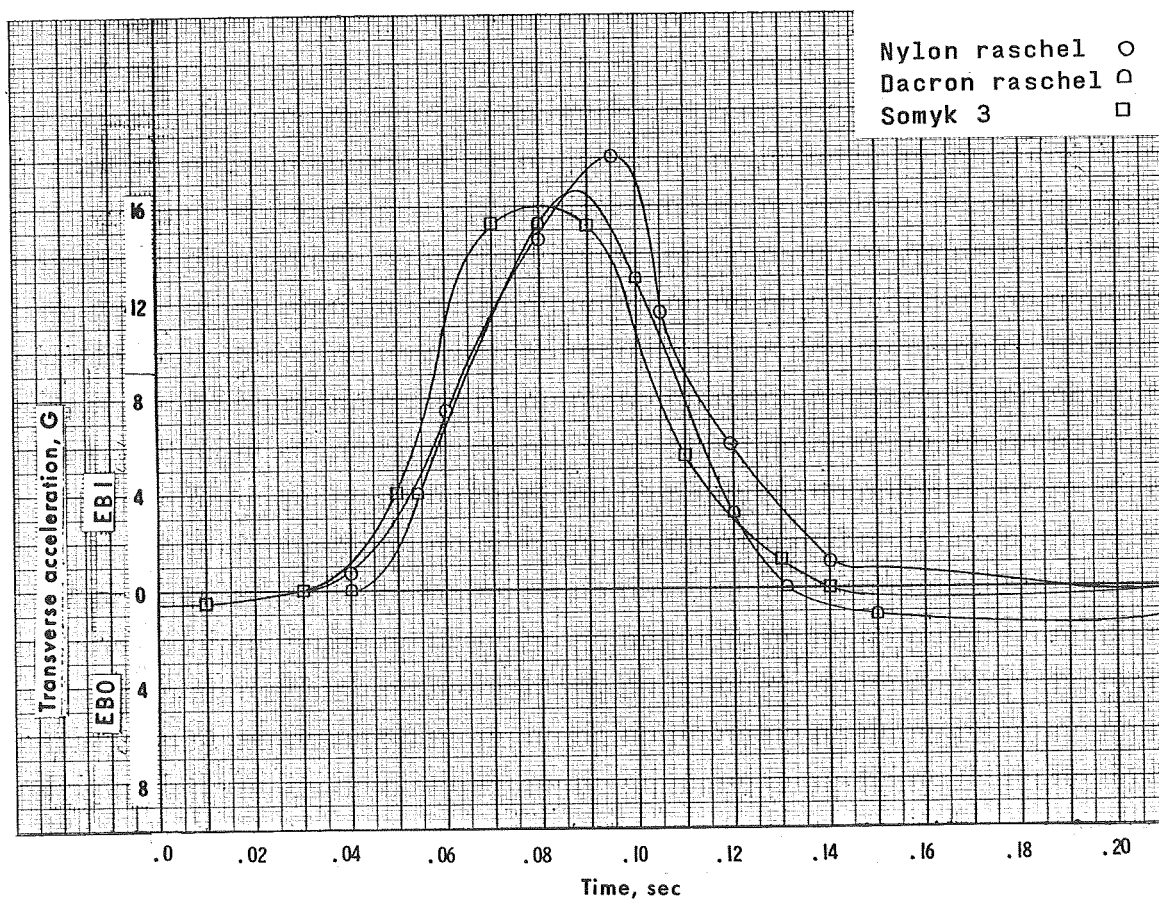
(c) Mercury torso drops

Figure 6.- Concluded.



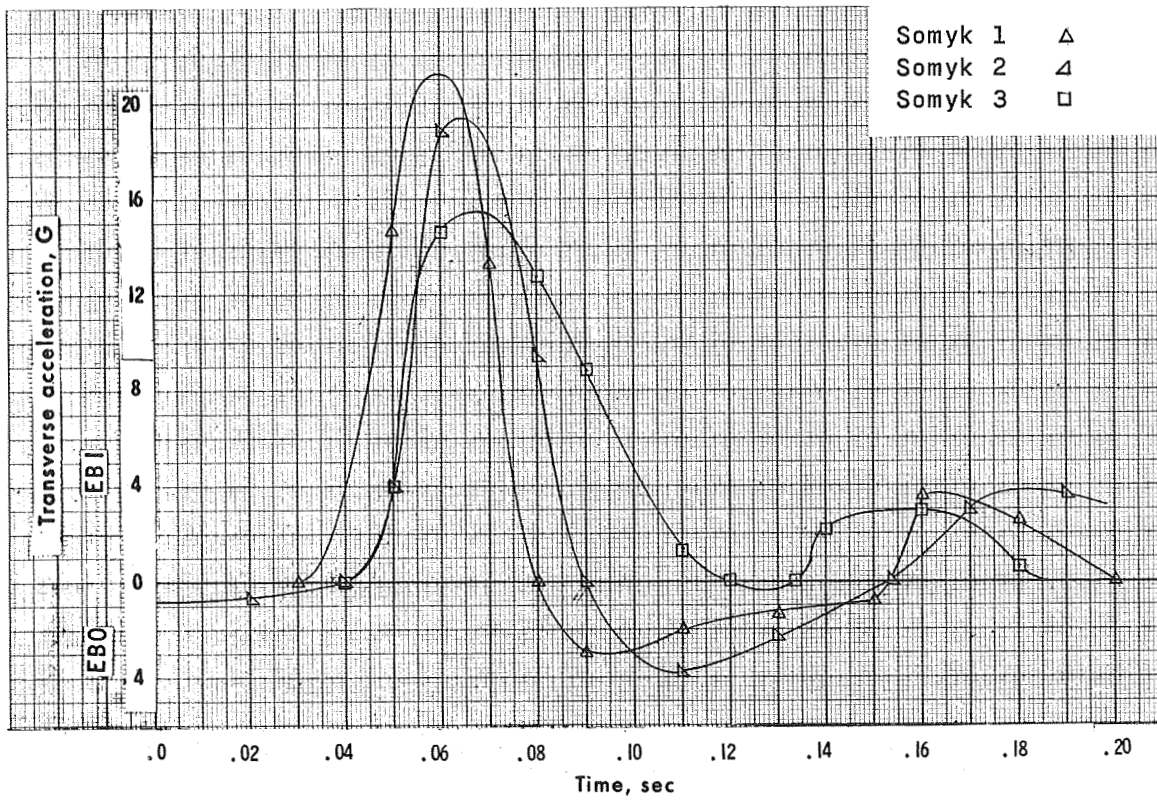
(a) Head

Figure 7.- Comparison of the impact loads measured on an anthropometric dummy using various netting type body supports. $V = 13.9$ ft/sec, $G = 12$.



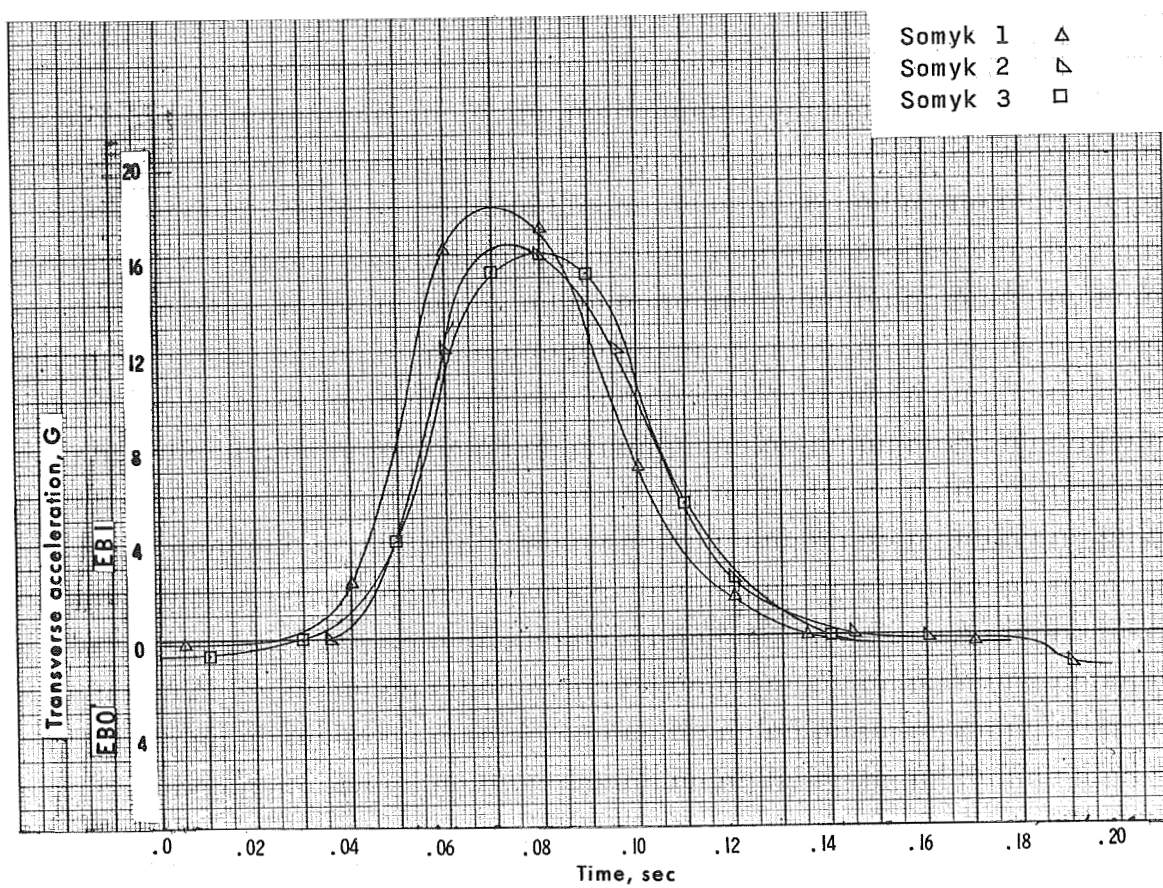
(b) Chest

Figure 7.- Concluded.



(a) Head

Figure 8.- Comparison of the impact loads measured on an anthropometric dummy using various netting type body supports. $V = 13.9$ ft/sec, $G = 12$.



(b) Chest

Figure 8.- Concluded.

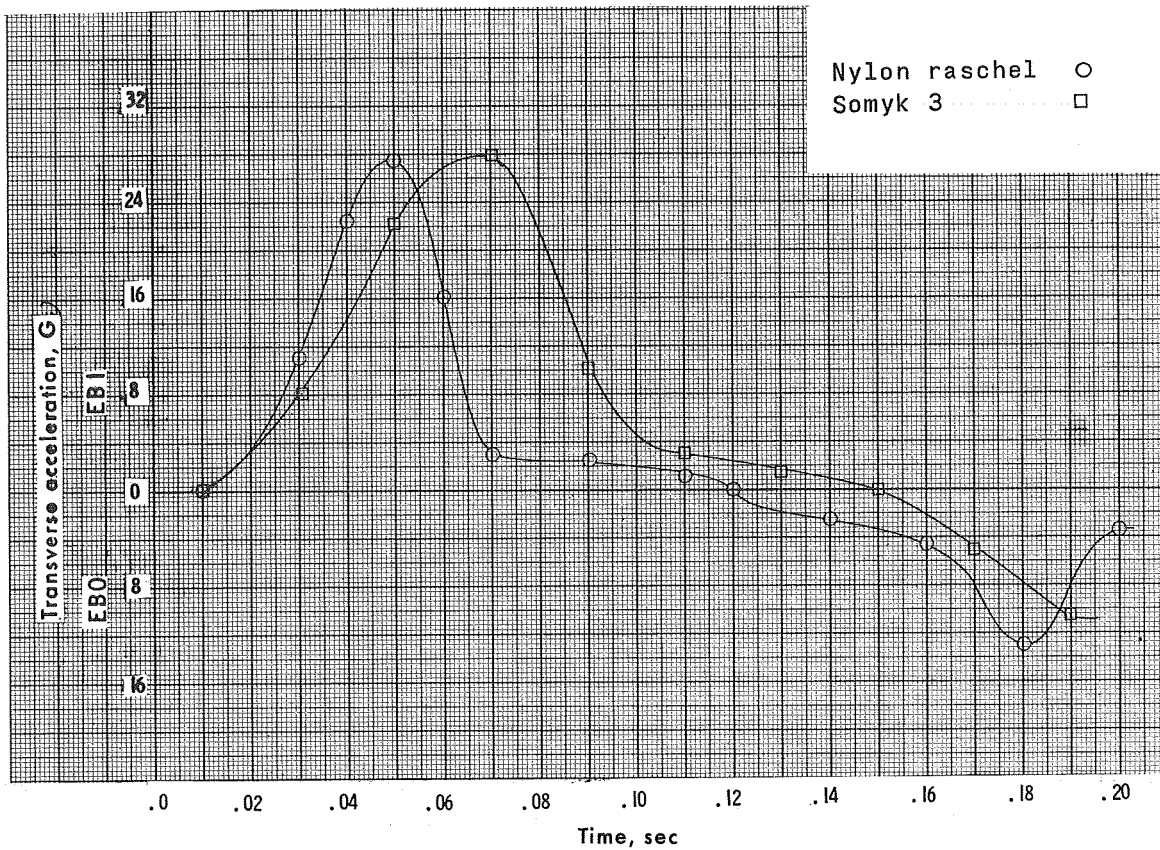


Figure 9.- Comparison of the impact loads measured on an anthropometric dummy using various netting type body supports. $V = 30$ ft/sec, $G = 20$. (Head)

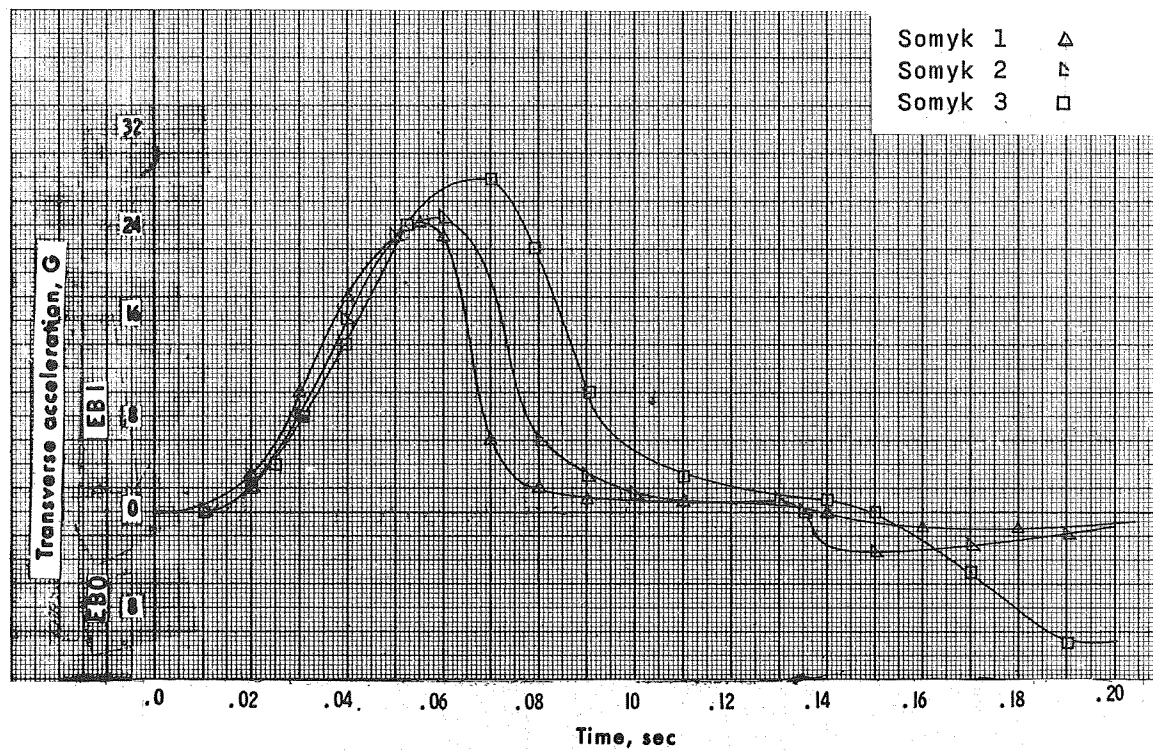
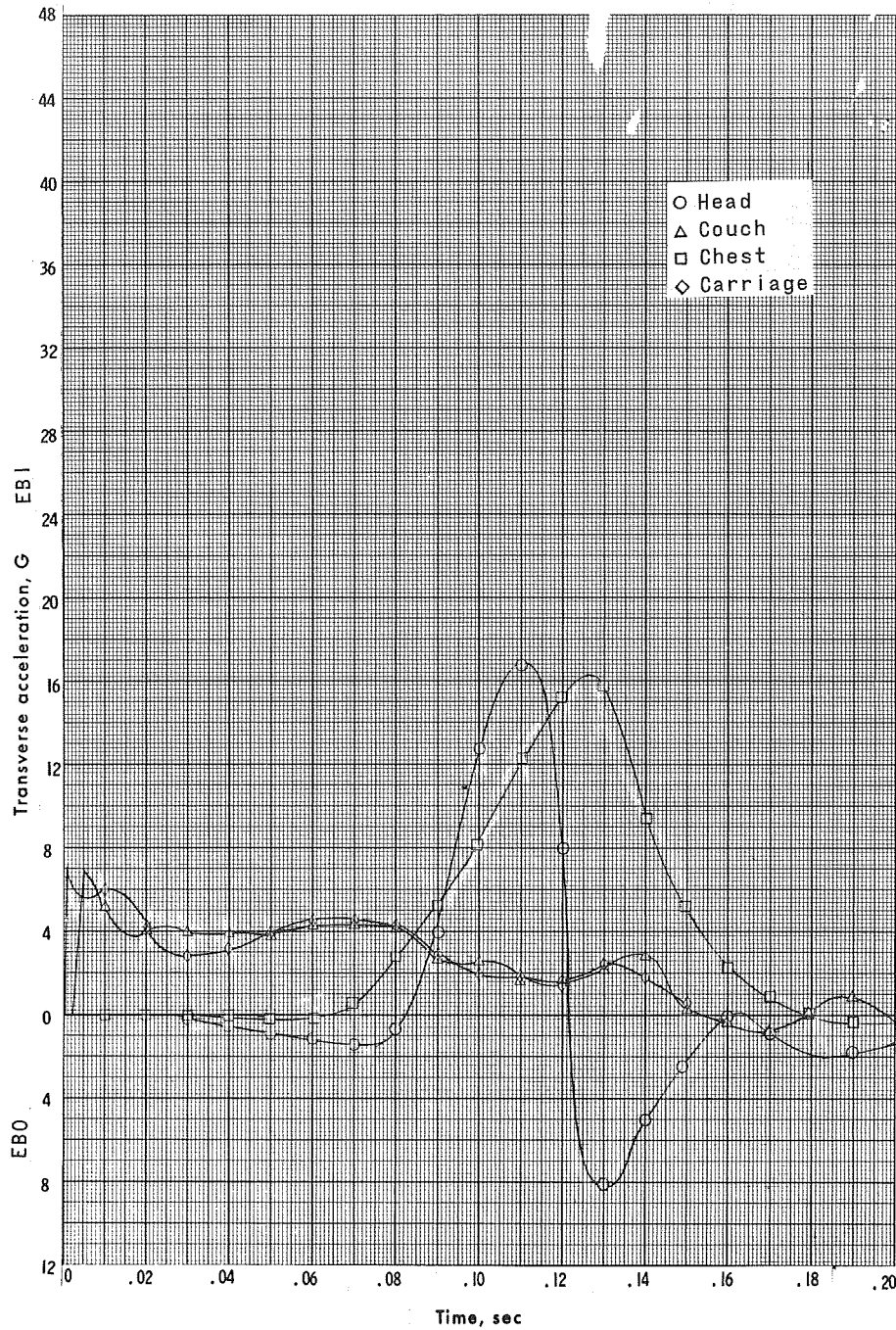
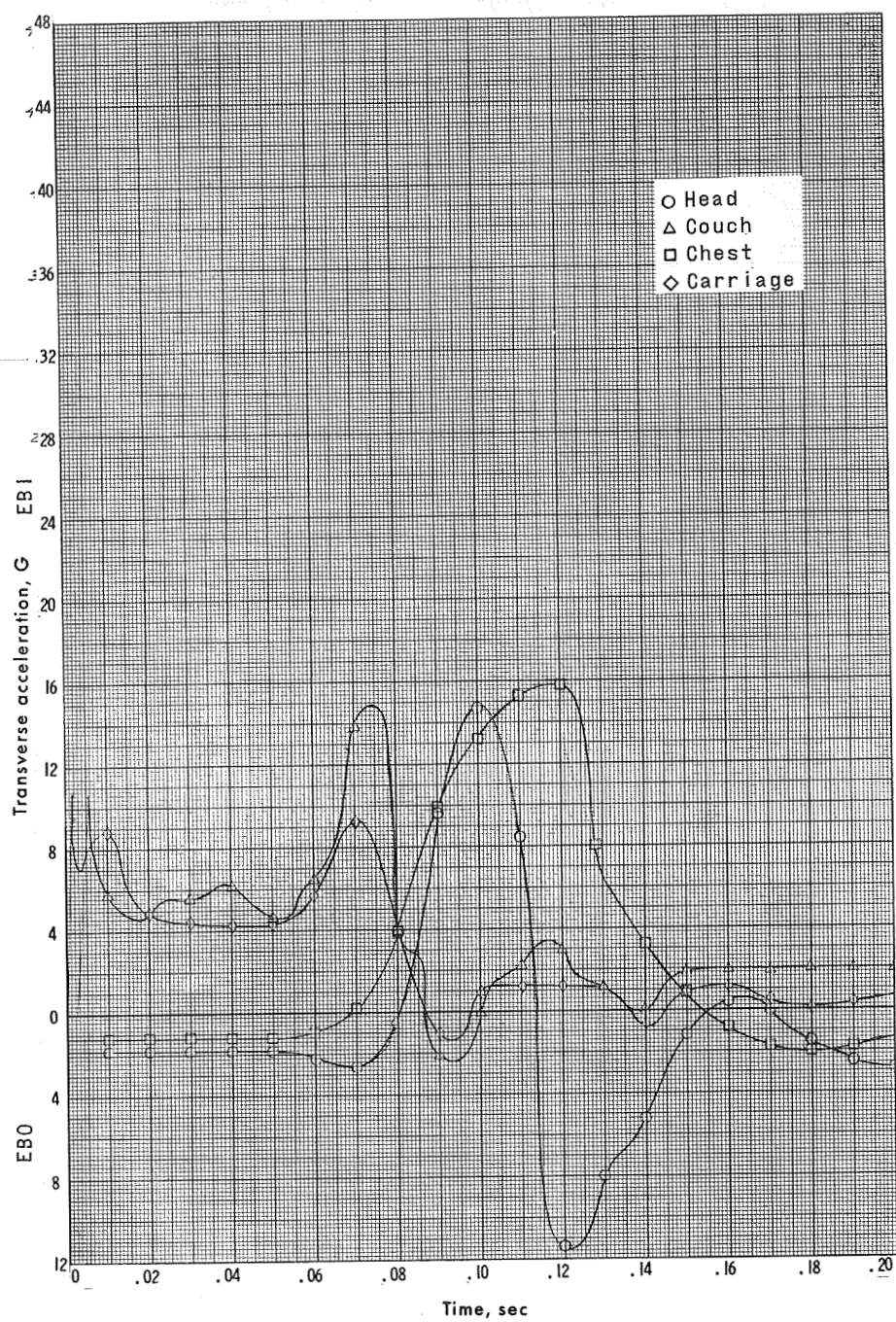


Figure 10.- Comparison of the impact loads measured on an anthropometric dummy using various netting type body supports. $V = 30$ ft/sec, $G = 20$. (Head).



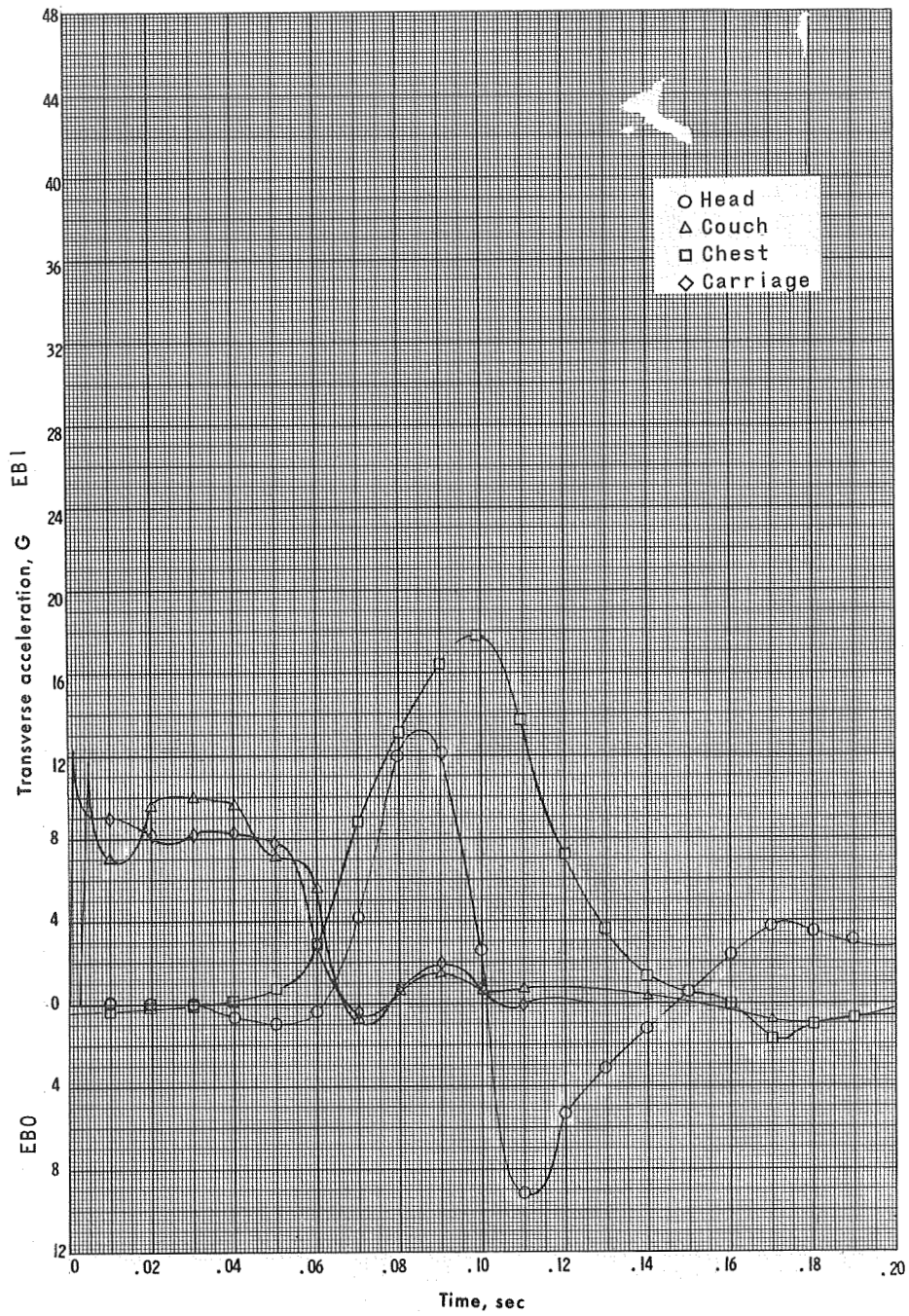
(a) Induced load 4G

Figure 11.- Acceleration-time histories measured on an anthropometric dummy using nylon raschel net type body support under various induced loads. $V_i = 13.9$ ft/sec.



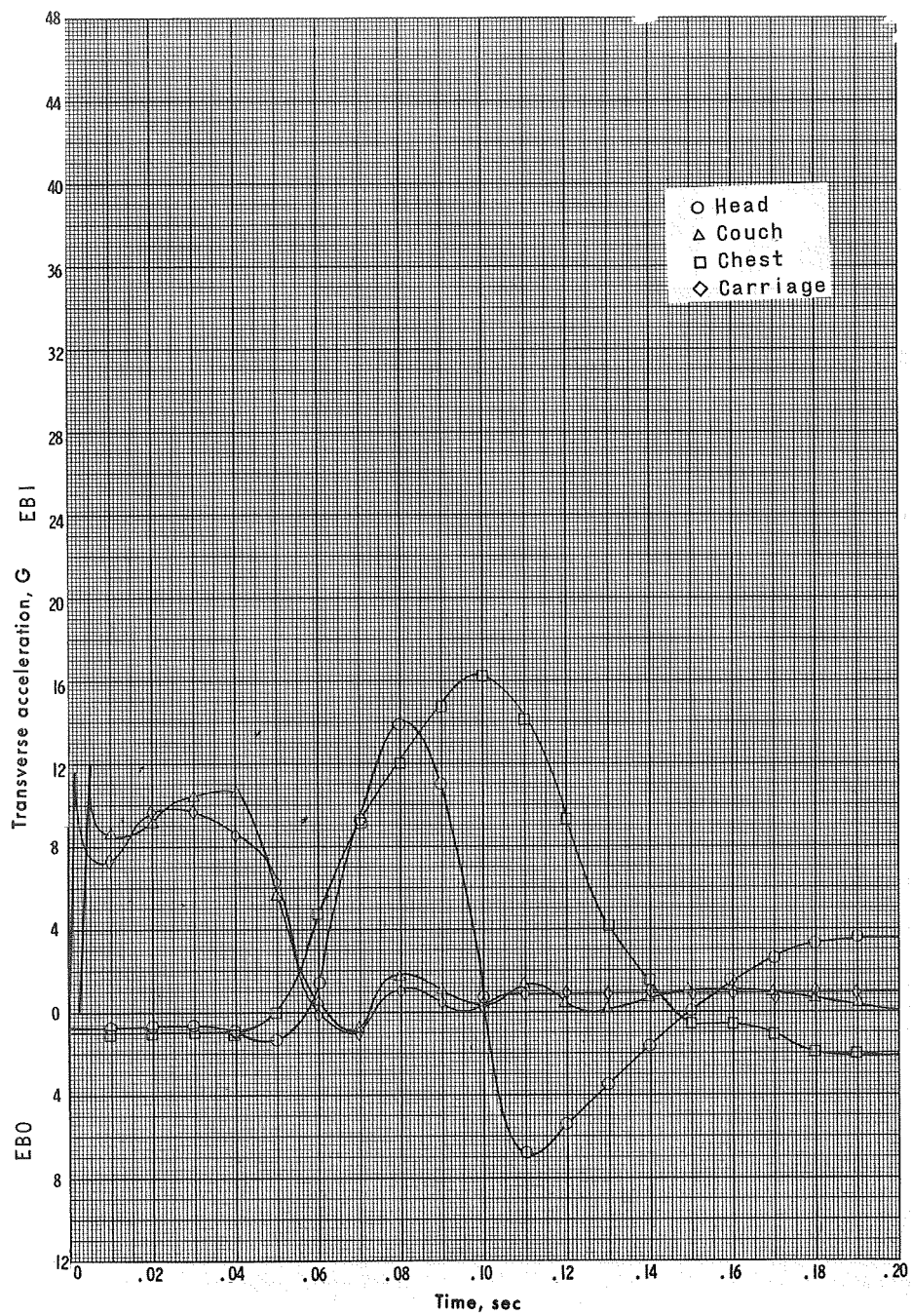
(b) Induced load 6G

Figure 11.- Continued.



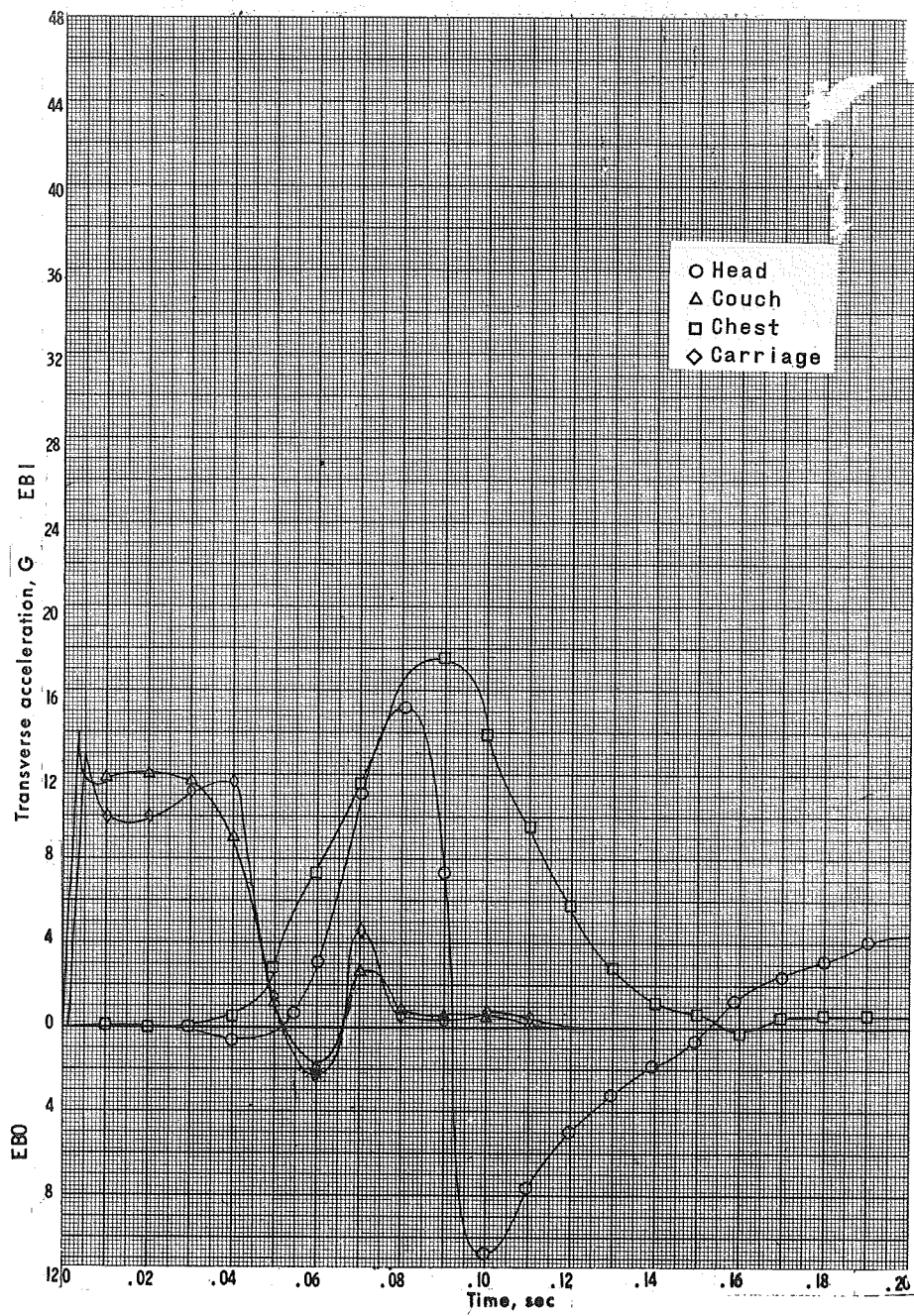
(c) Induced load 8G

Figure 11.- Continued.



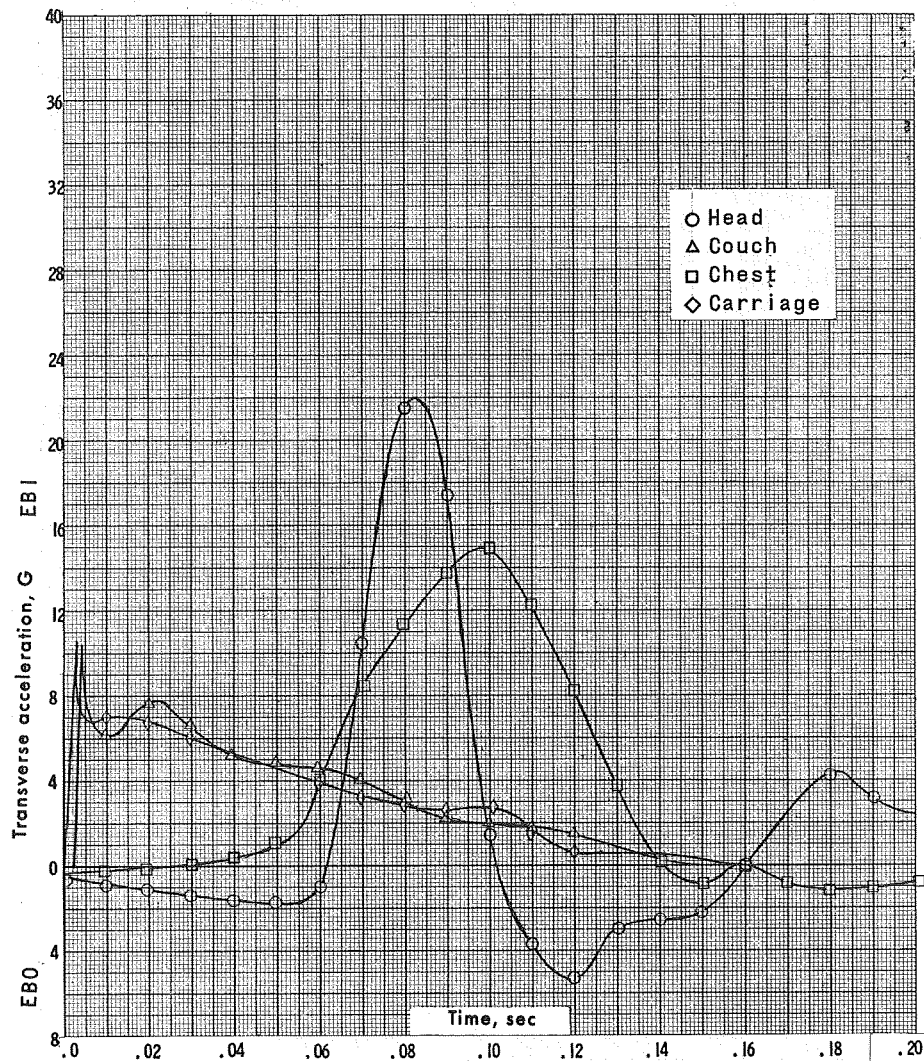
(d) Induced load 10G

Figure 11.- Continued.



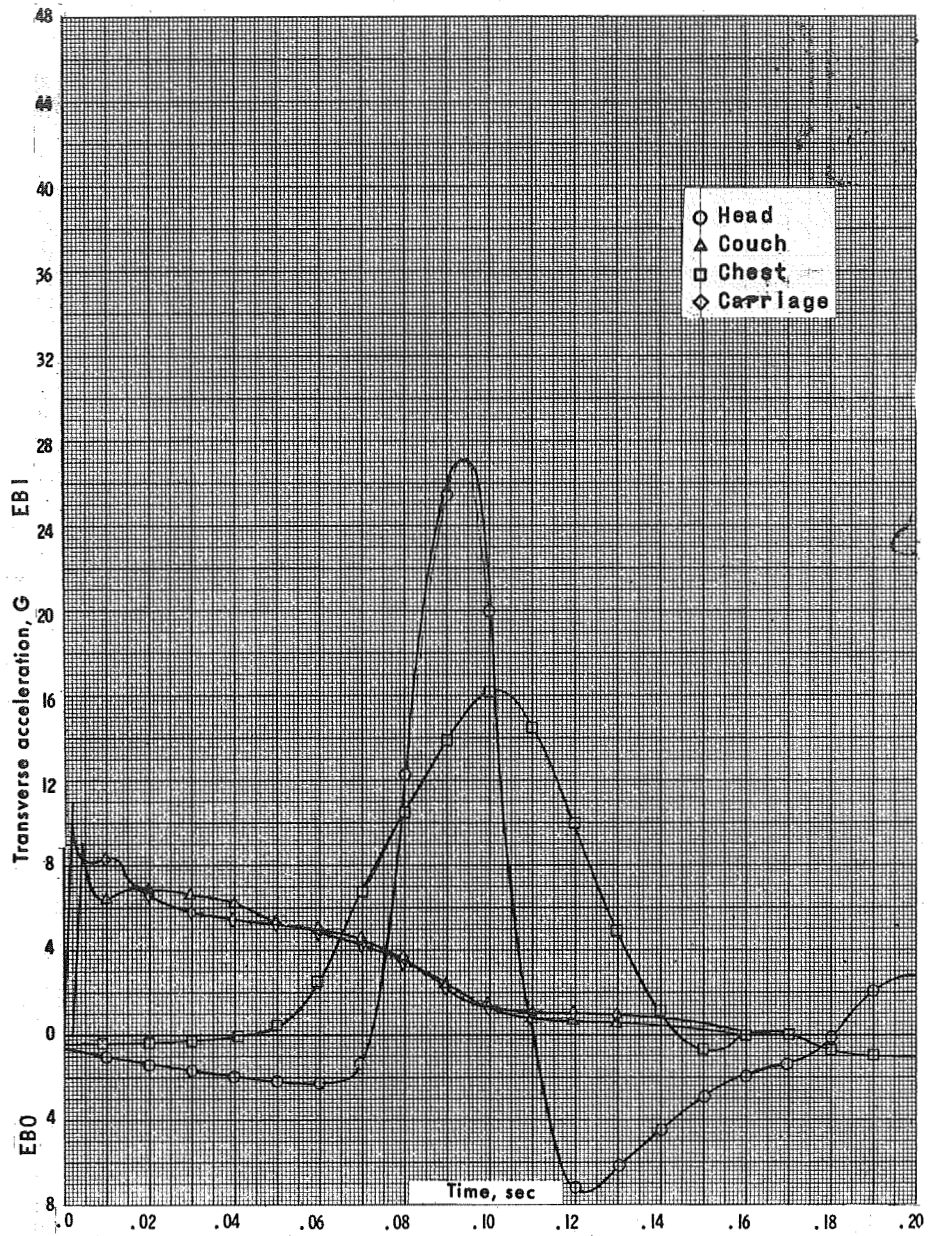
(e) Induced load 12G

Figure 11.- Concluded.



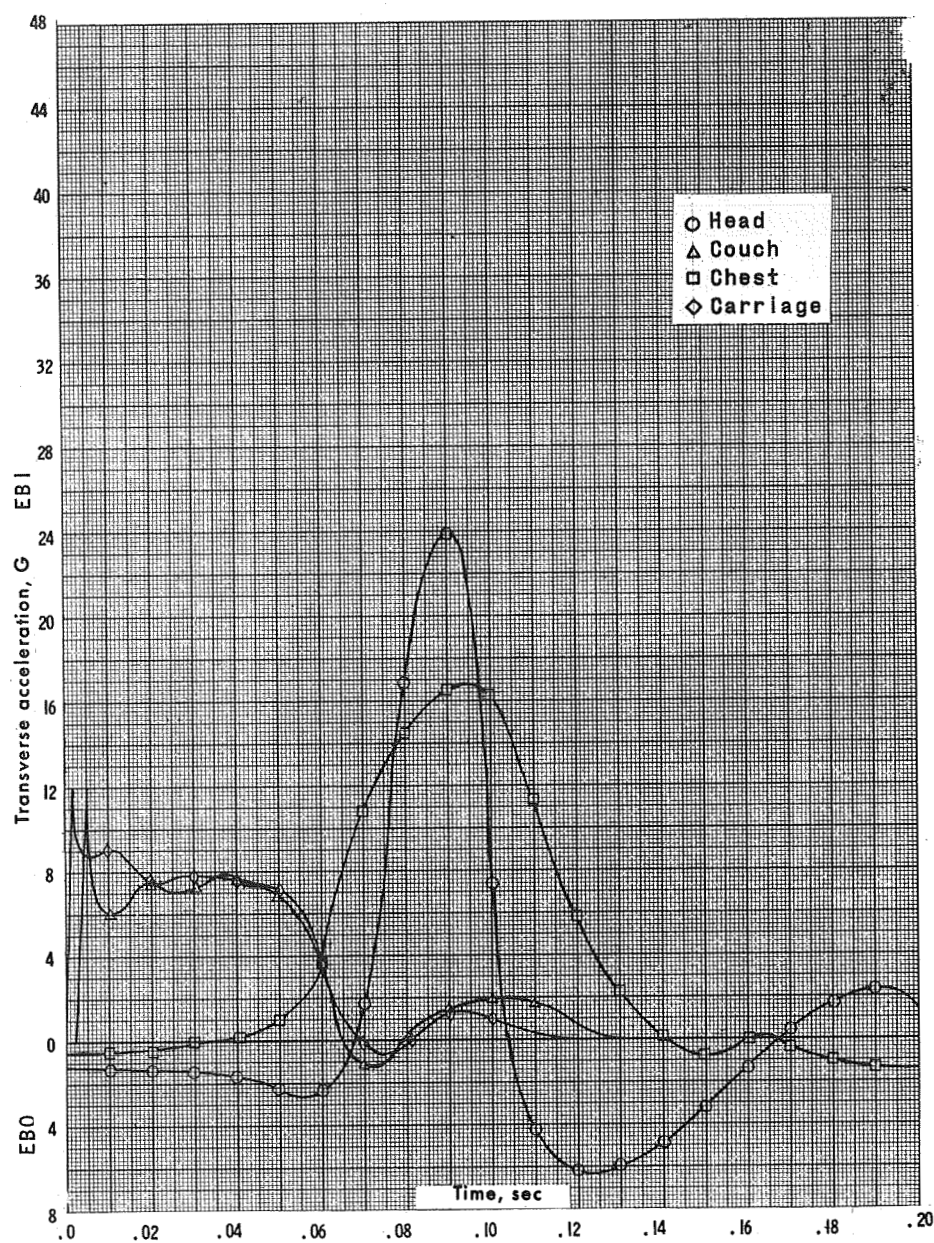
(a) Induced load 4G

Figure 12.- Acceleration-time histories measured on an anthropometric dummy using dacron raschel net type body support under various induced loads. $V_i = 13.9$ ft/sec.



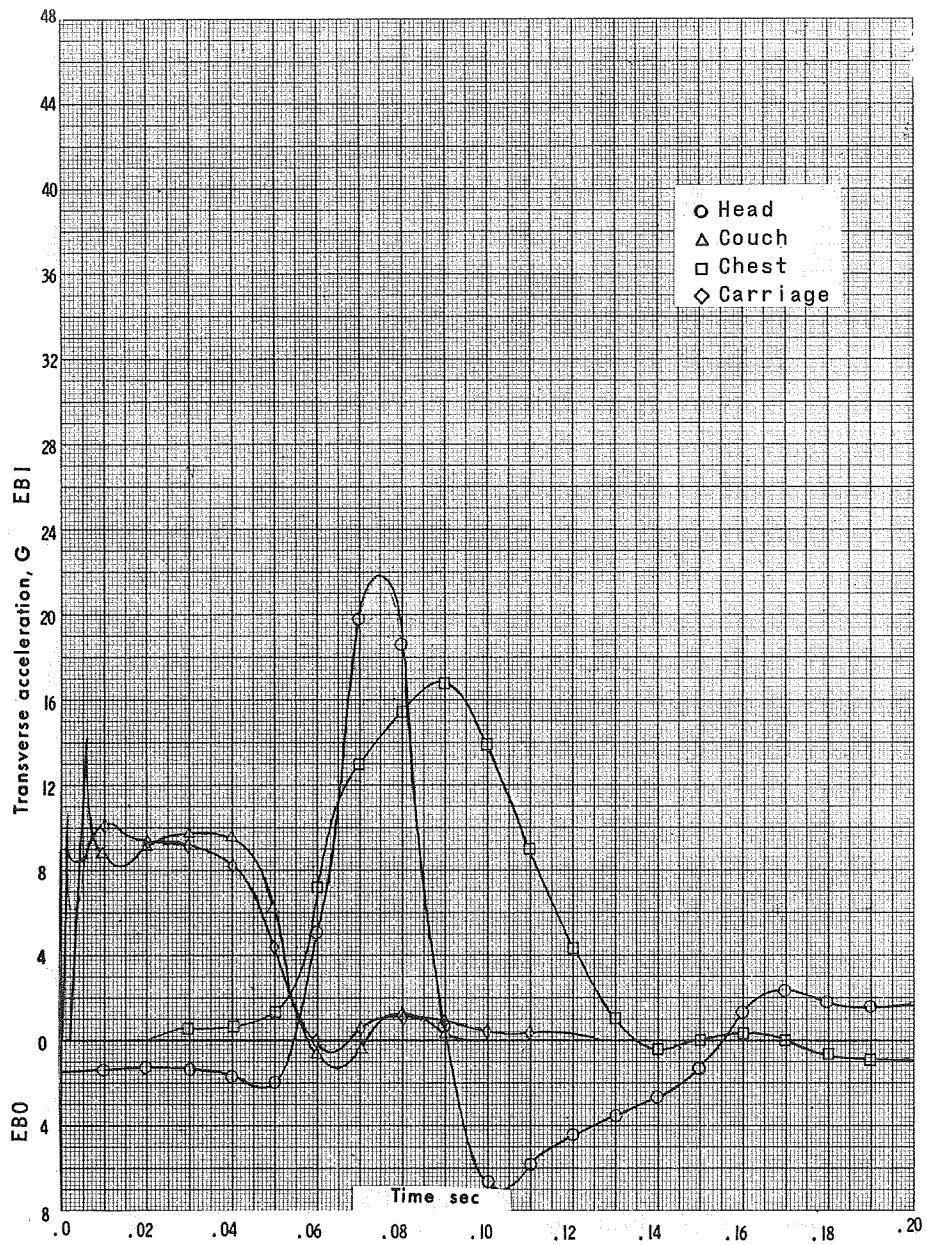
(b) Induced load 6G

Figure 12.- Continued.



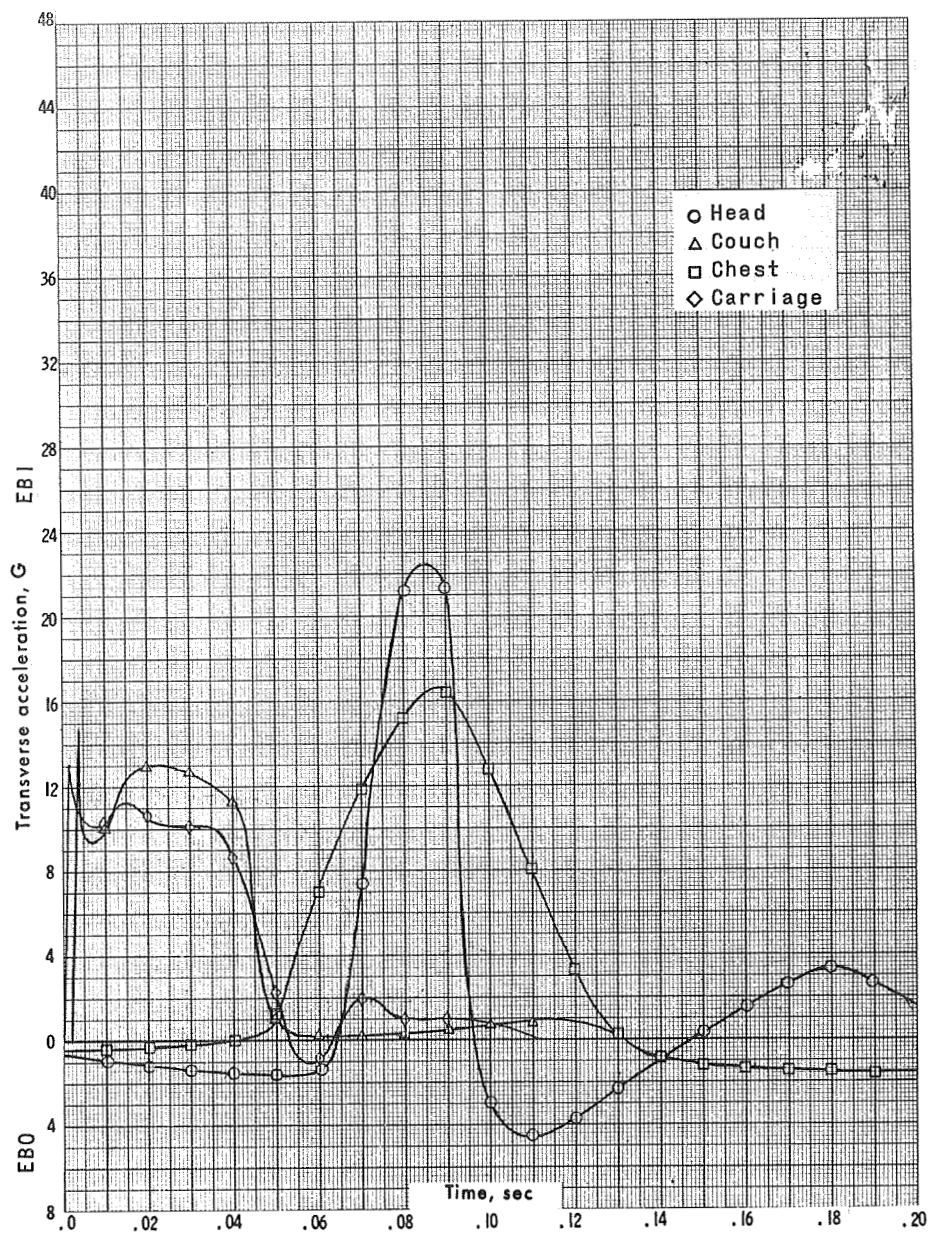
(c) Induced load 8G

Figure 12.- Continued.



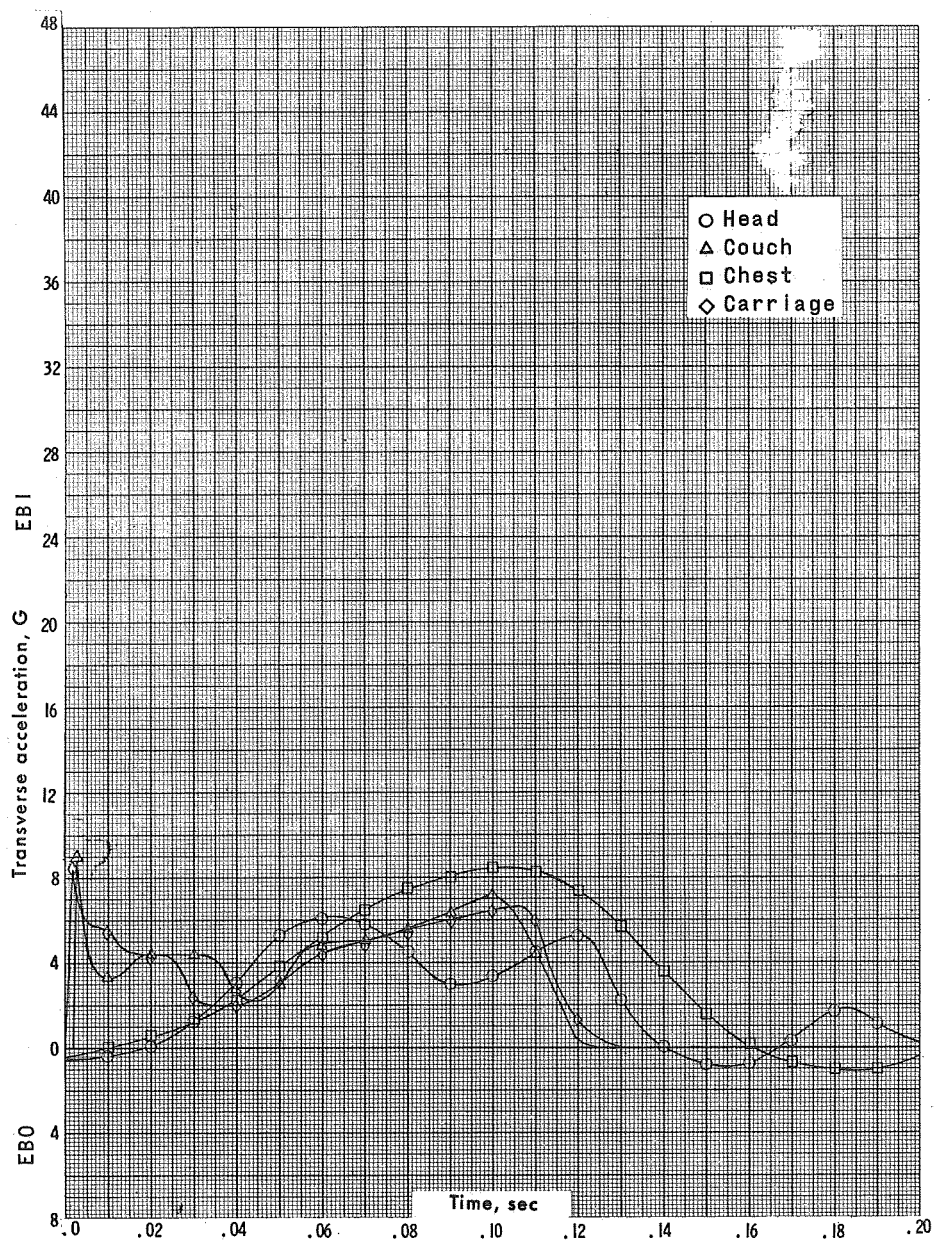
(d) Induced load 10G

Figure 12.- Continued.



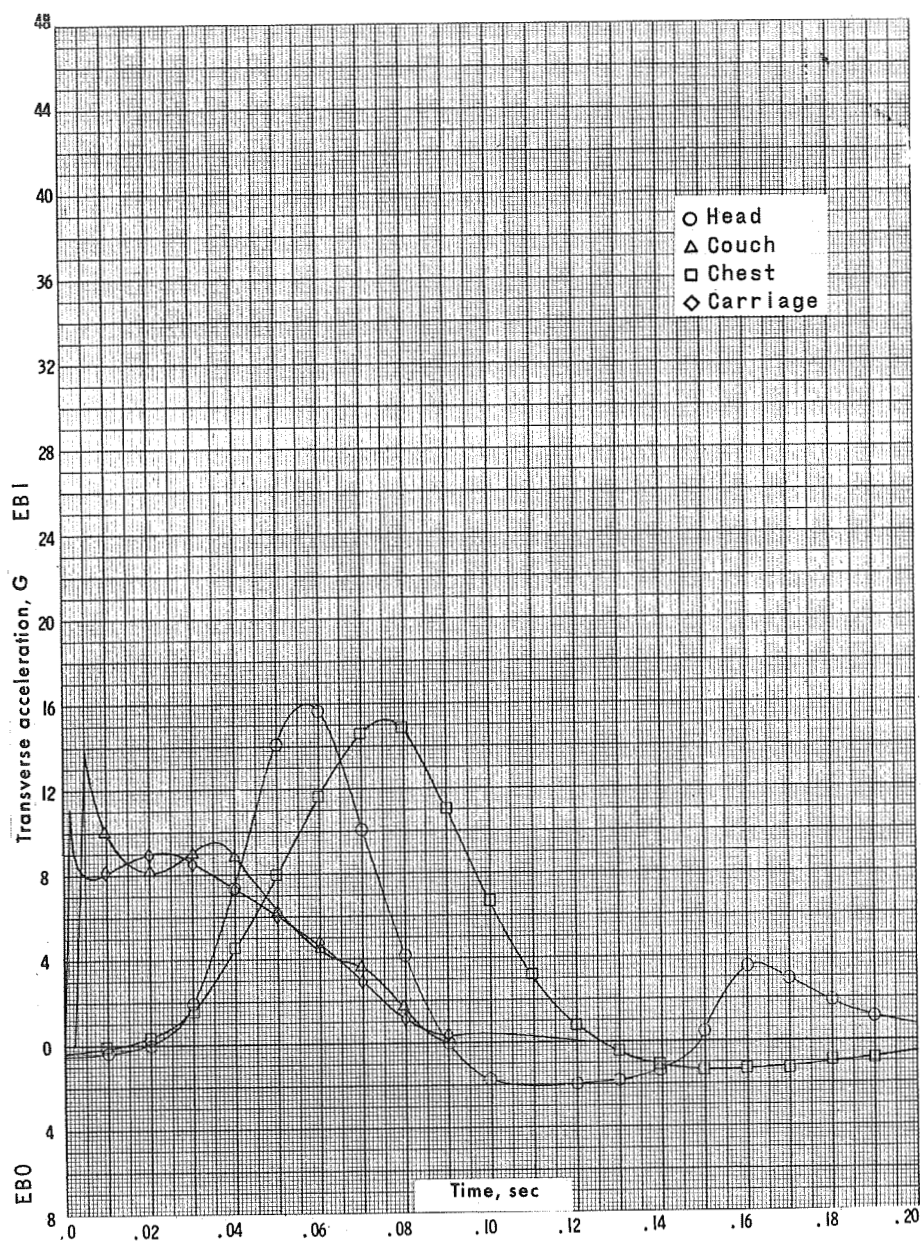
(e) Induced load 12G

Figure 12.- Concluded.



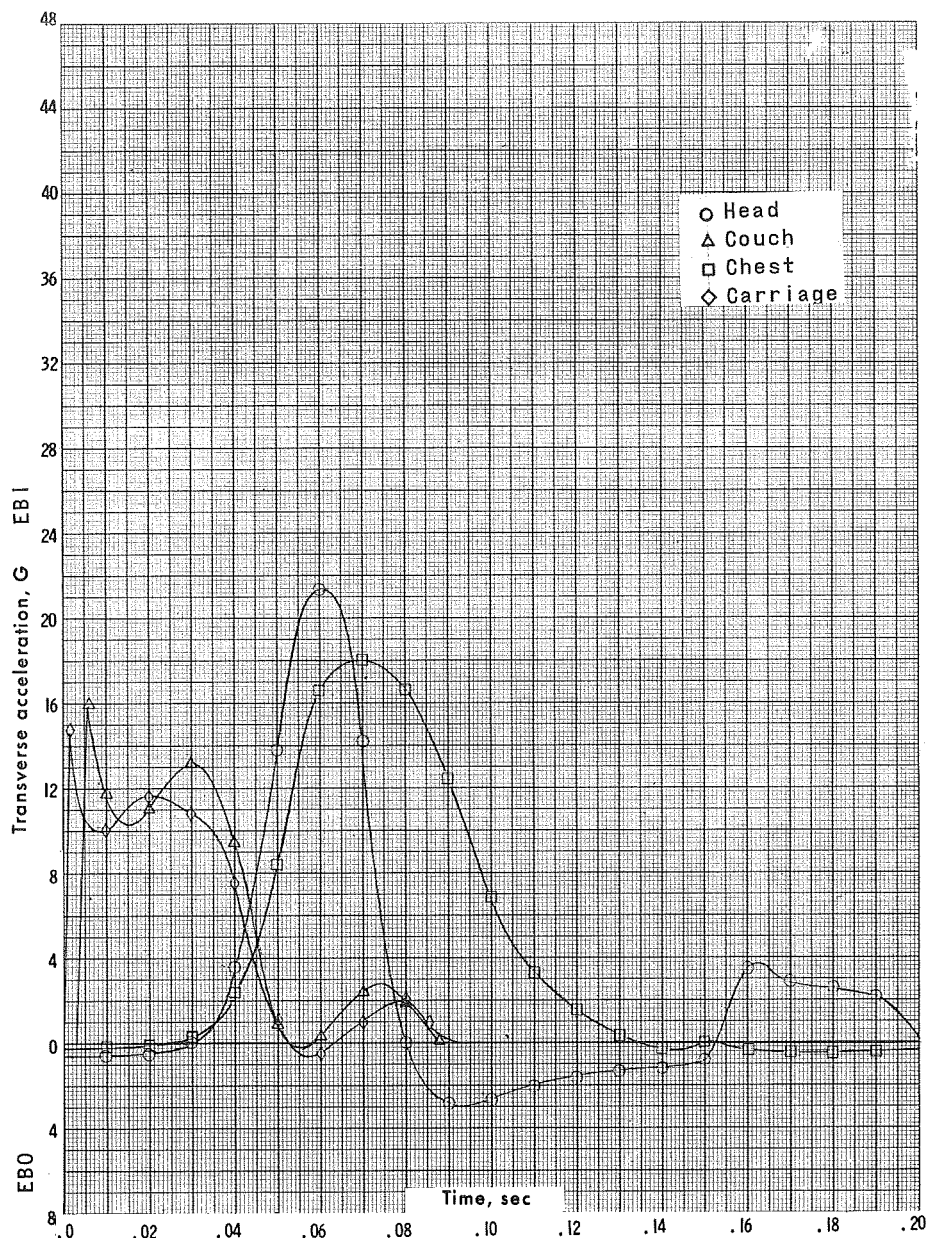
(a) Induced load 4G

Figure 13.- Acceleration-time histories measured on an anthropometric dummy using Somyk type 1 net type body support under various induced loads. $V_i = 13.9$ ft/sec.



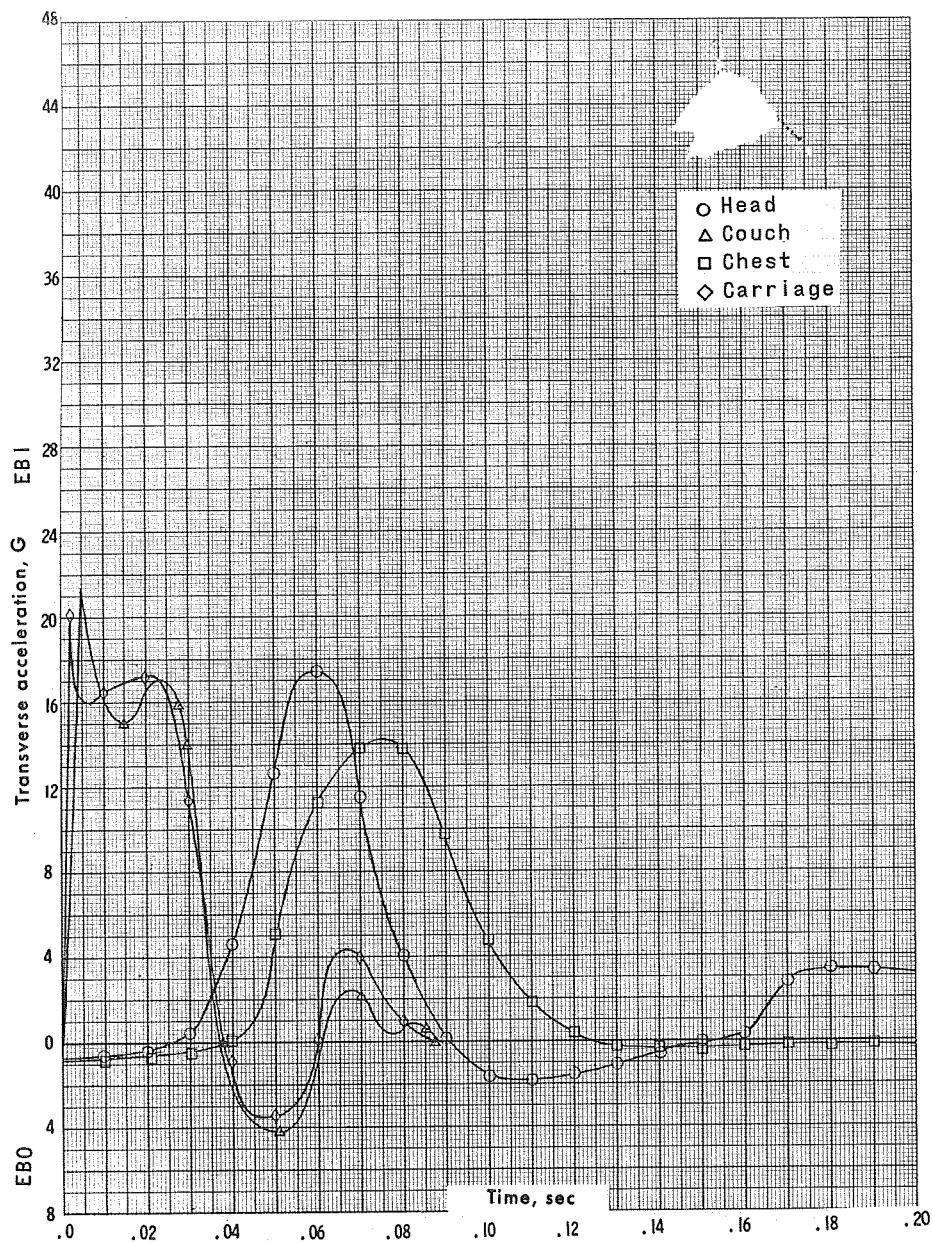
(b) Induced load 8G

Figure 13.- Continued.



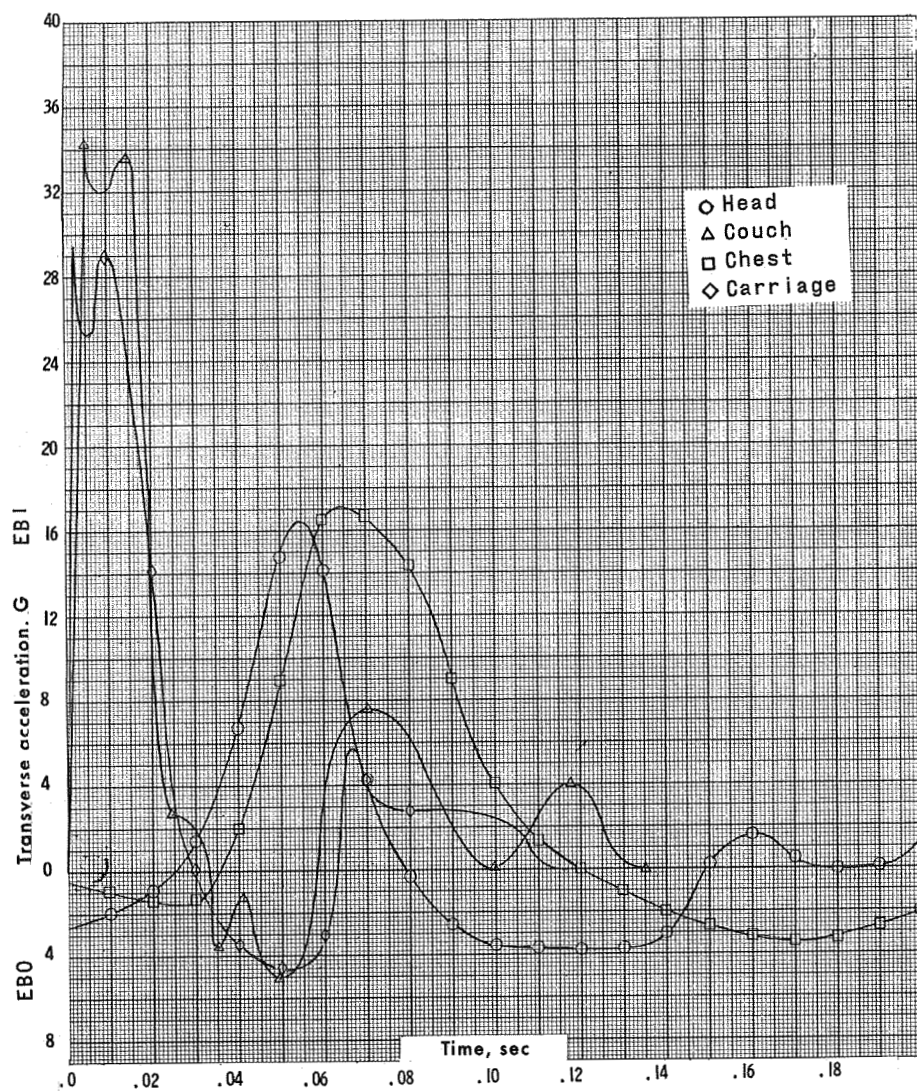
(c) Induced load 12G

Figure 13.- Continued.



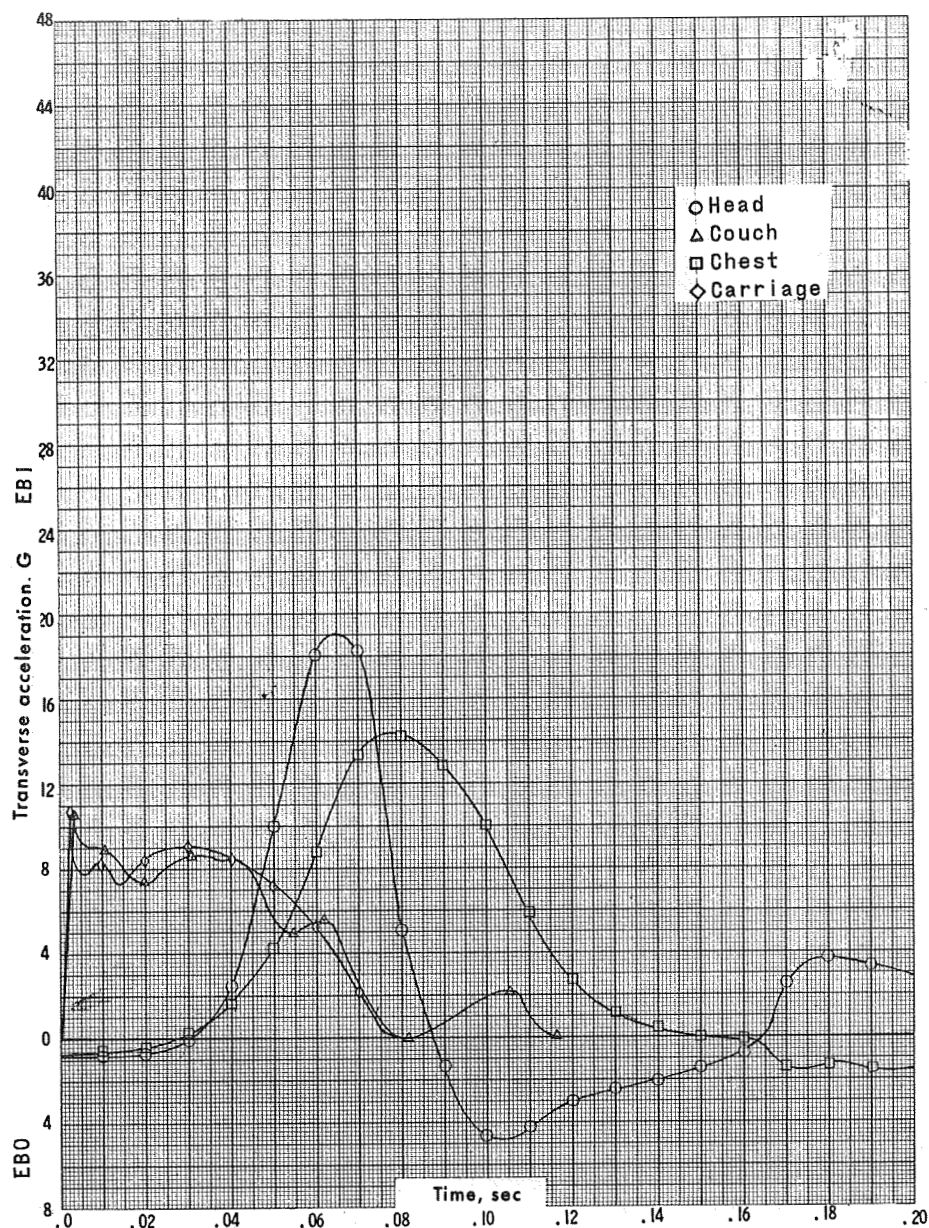
(d) Induced load 16G

Figure 13.- Continued.



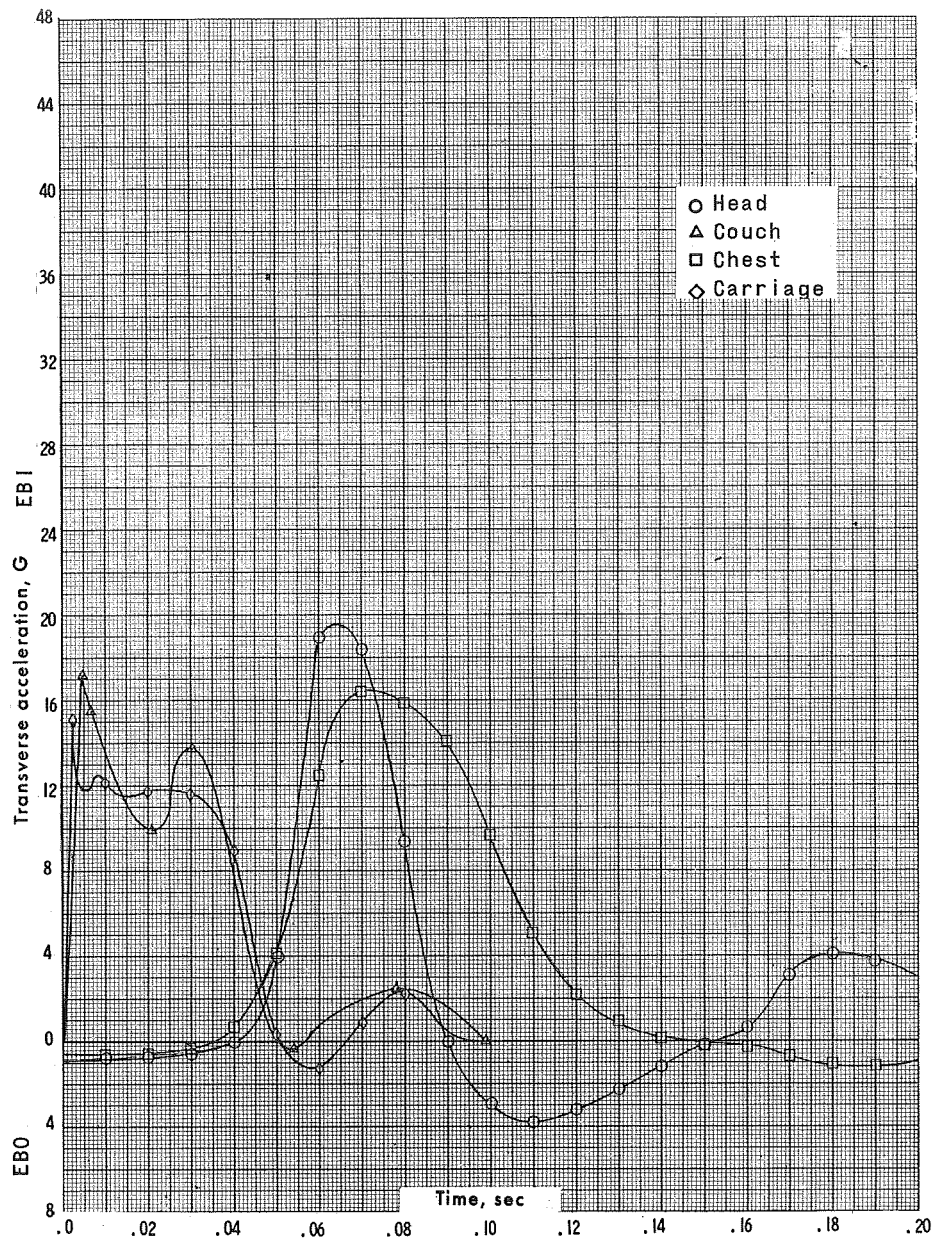
(e) Induced load 30G

Figure 13.- Concluded.



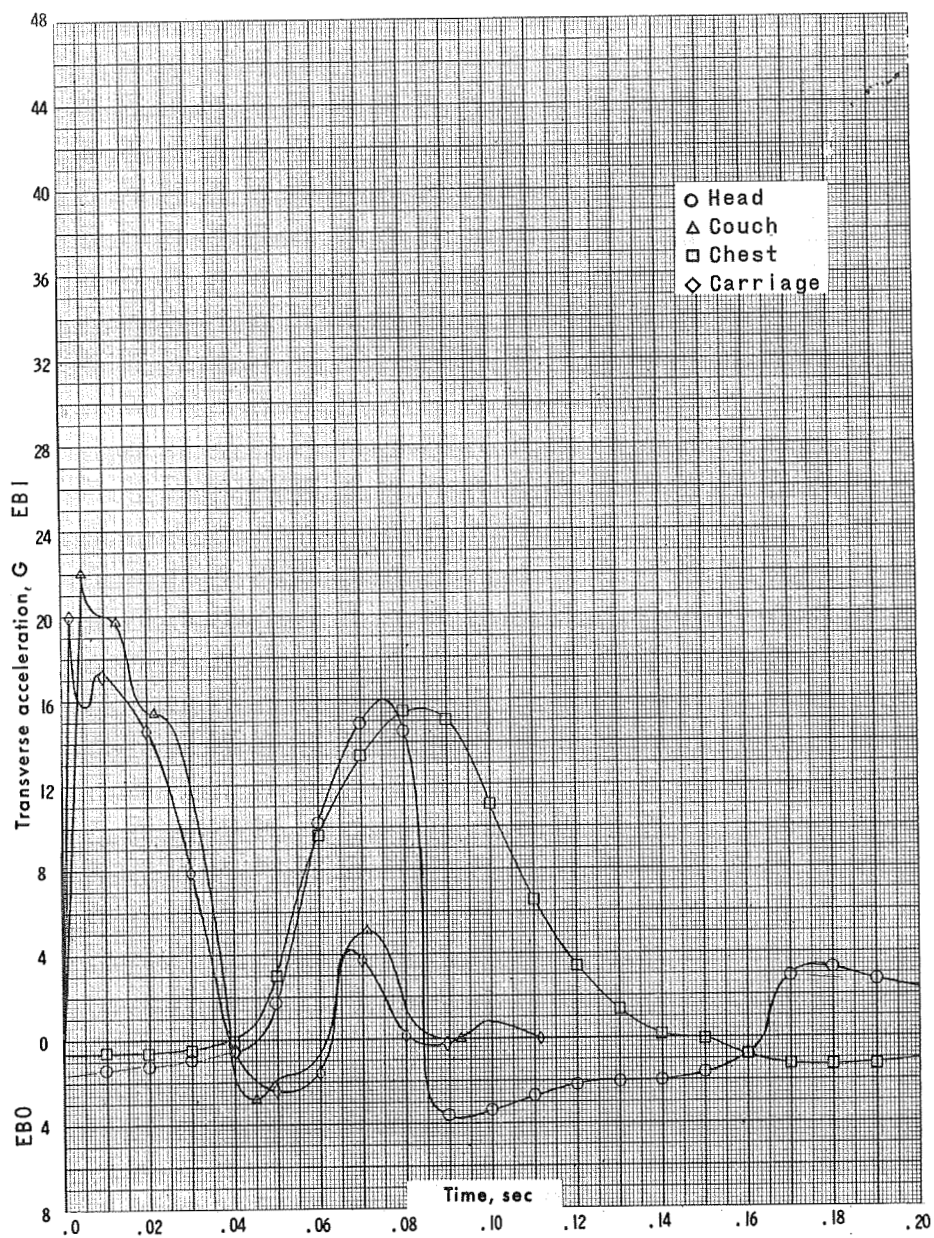
(a) Induced load 8G

Figure 14.- Acceleration-time histories measured on an anthropometric dummy using Somyk type 2 net type body support under various induced loads. $V_i = 13.9$ ft/sec.



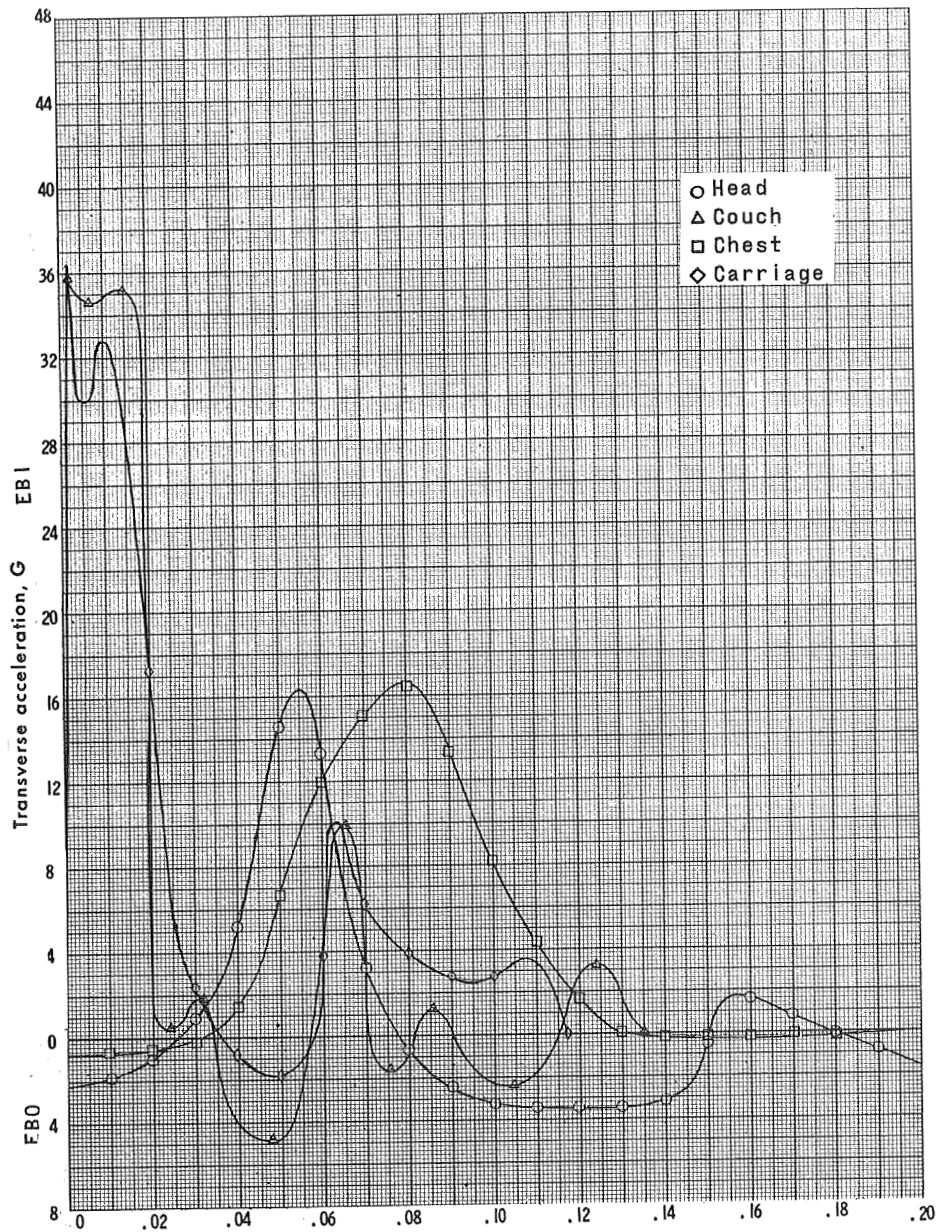
(b) Induced load 12G

Figure 14.- Continued.



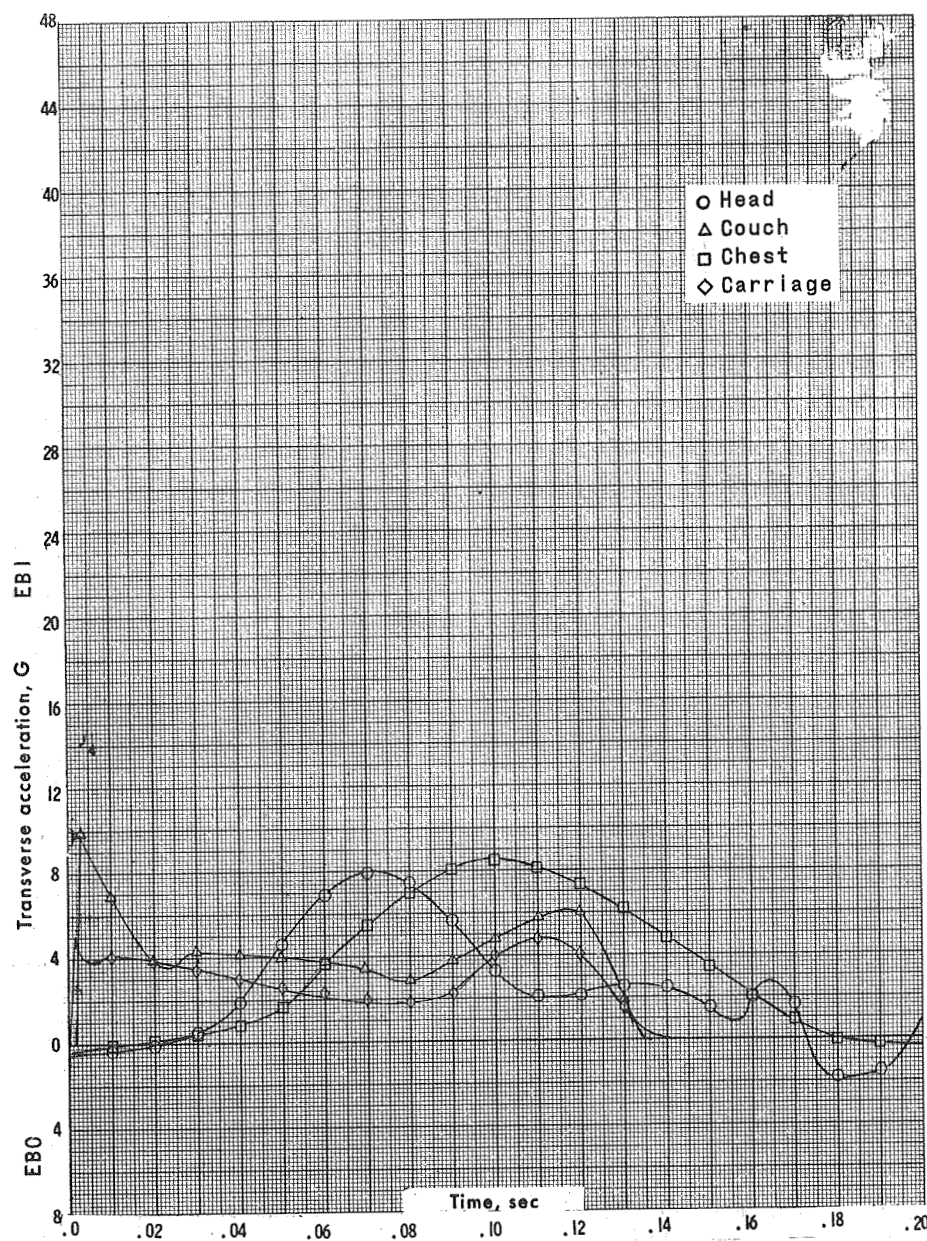
(c) Induced load 16G

Figure 14.- Continued.



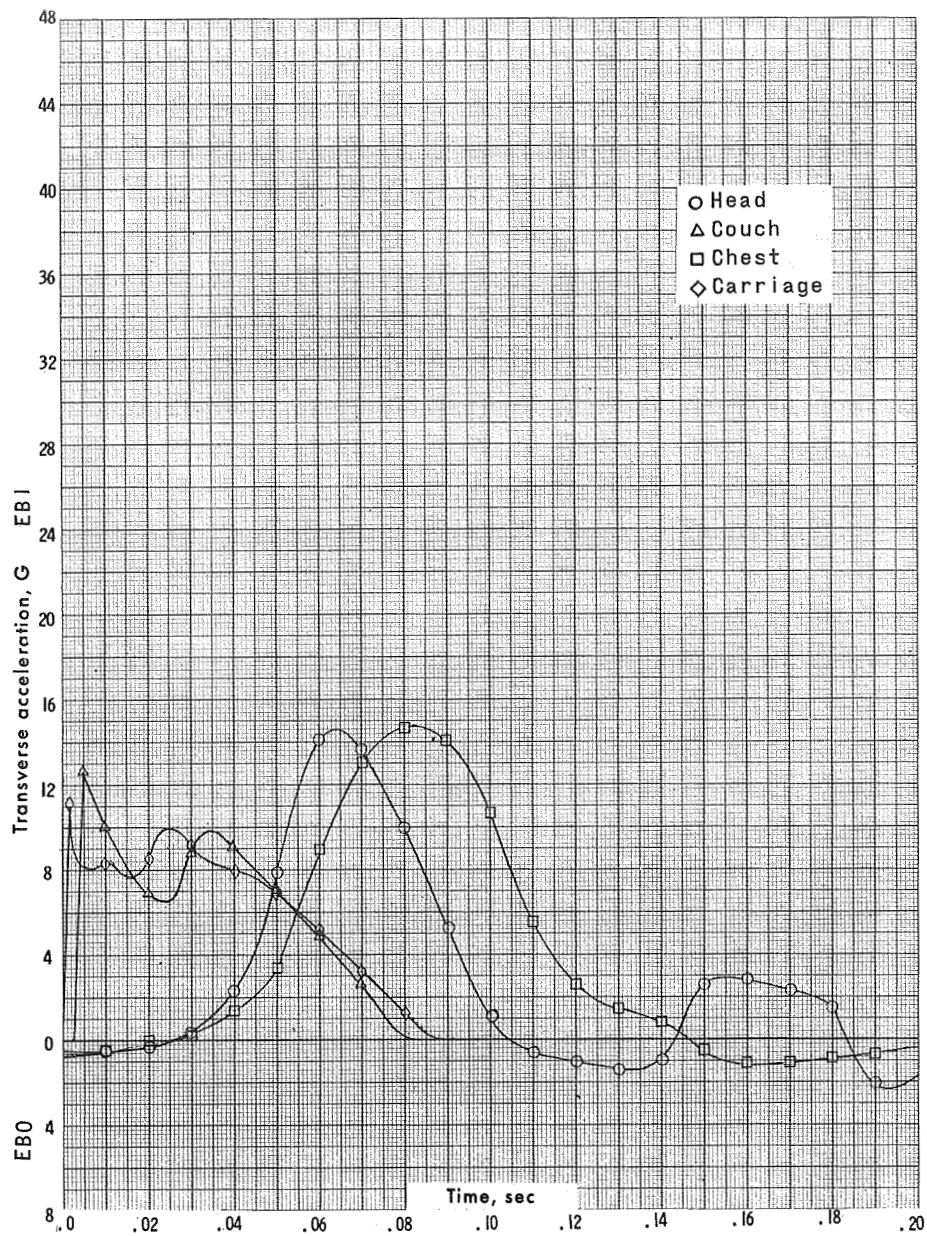
(d) Induced load 30G

Figure 14.- Concluded.



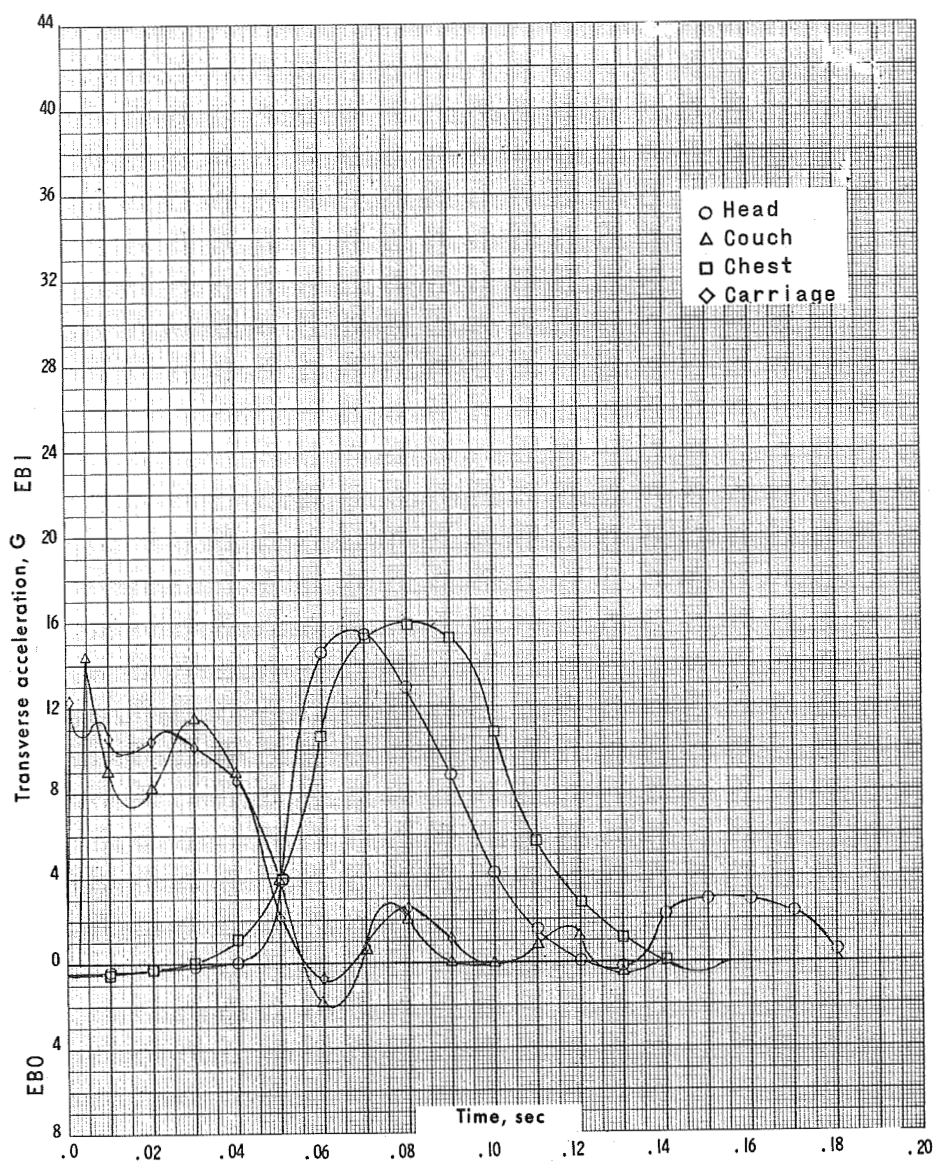
(a) Induced load 4G

Figure 15.- Acceleration-time histories measured on an anthropometric dummy using Somyk type 3 net type body support under various induced loads. $V_i = 13.9$ ft/sec.



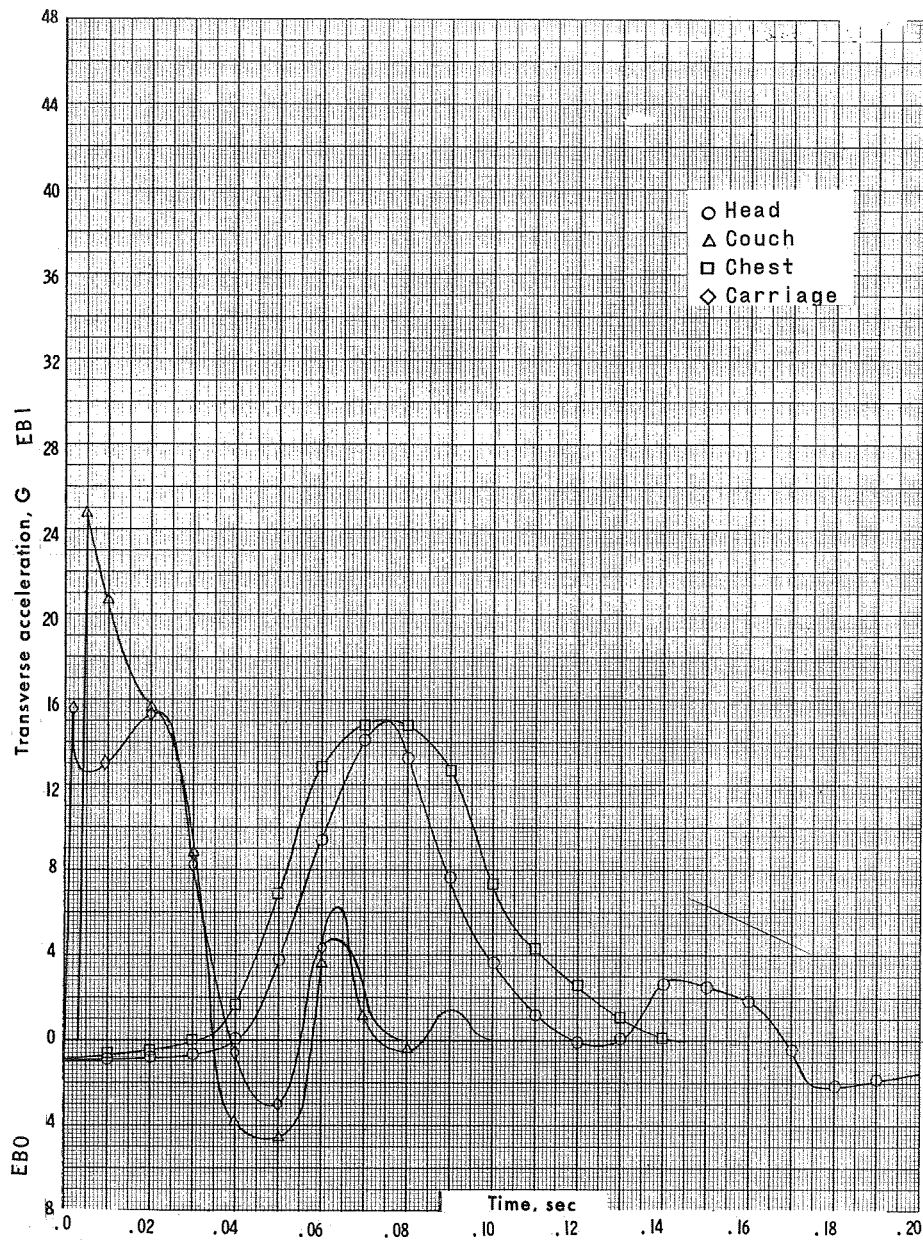
(b) Induced load 8G

Figure 15.- Continued.



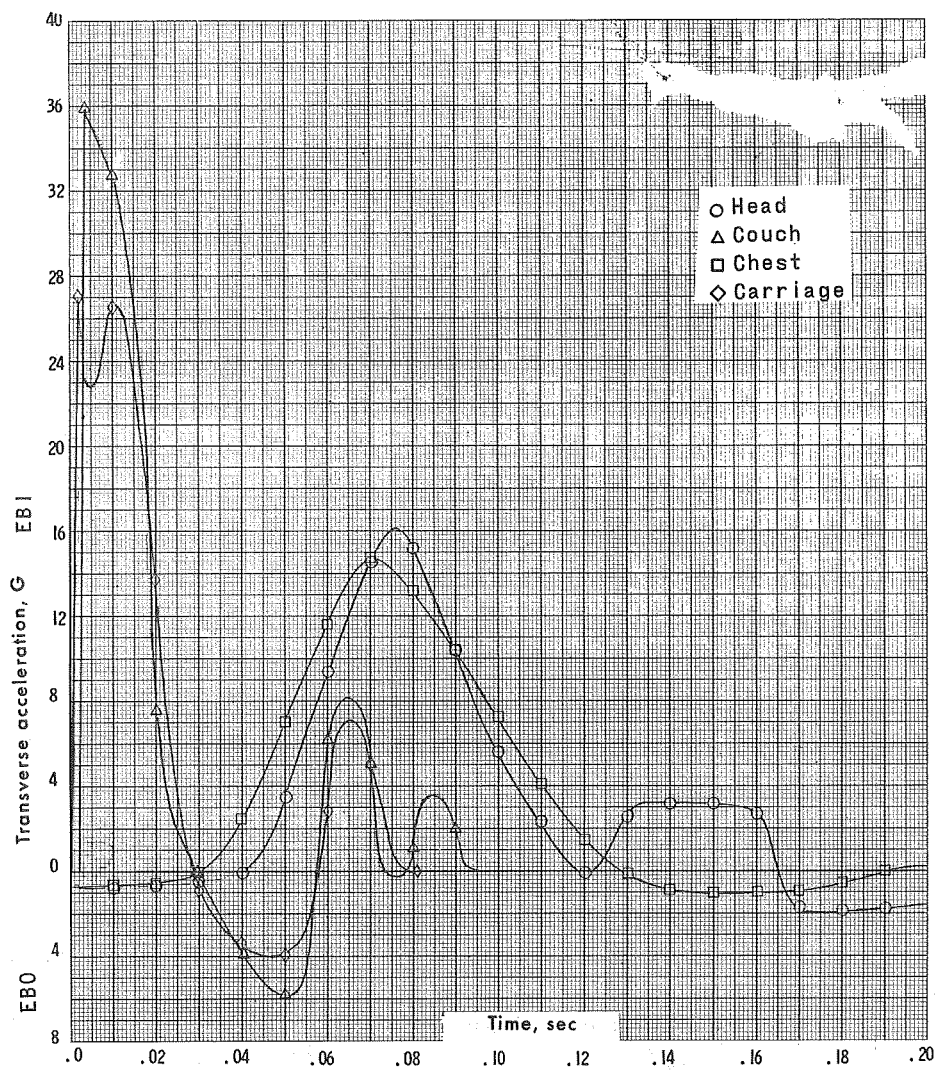
(c) Induced load 12G

Figure 15.- Continued.



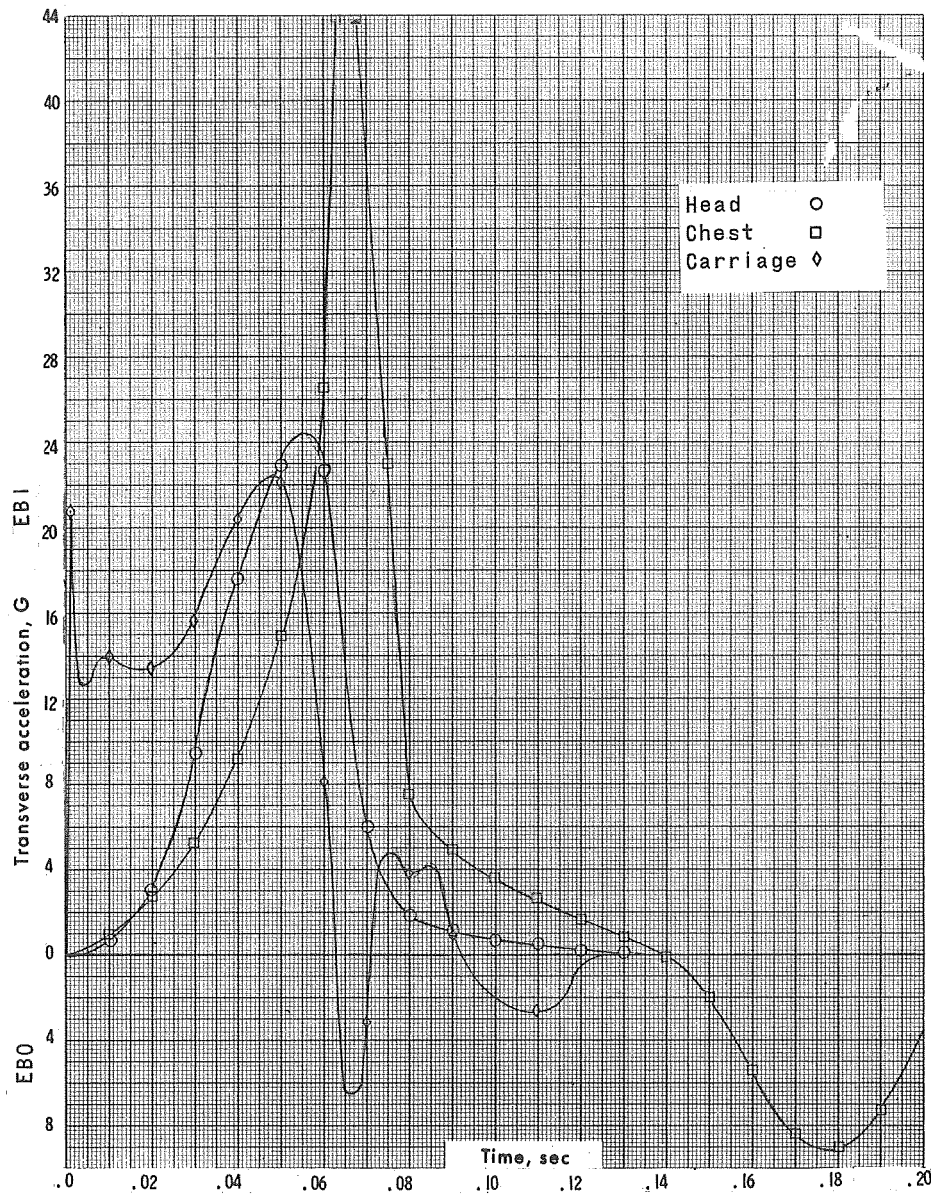
(d) Induced load 16G

Figure 15.- Continued.



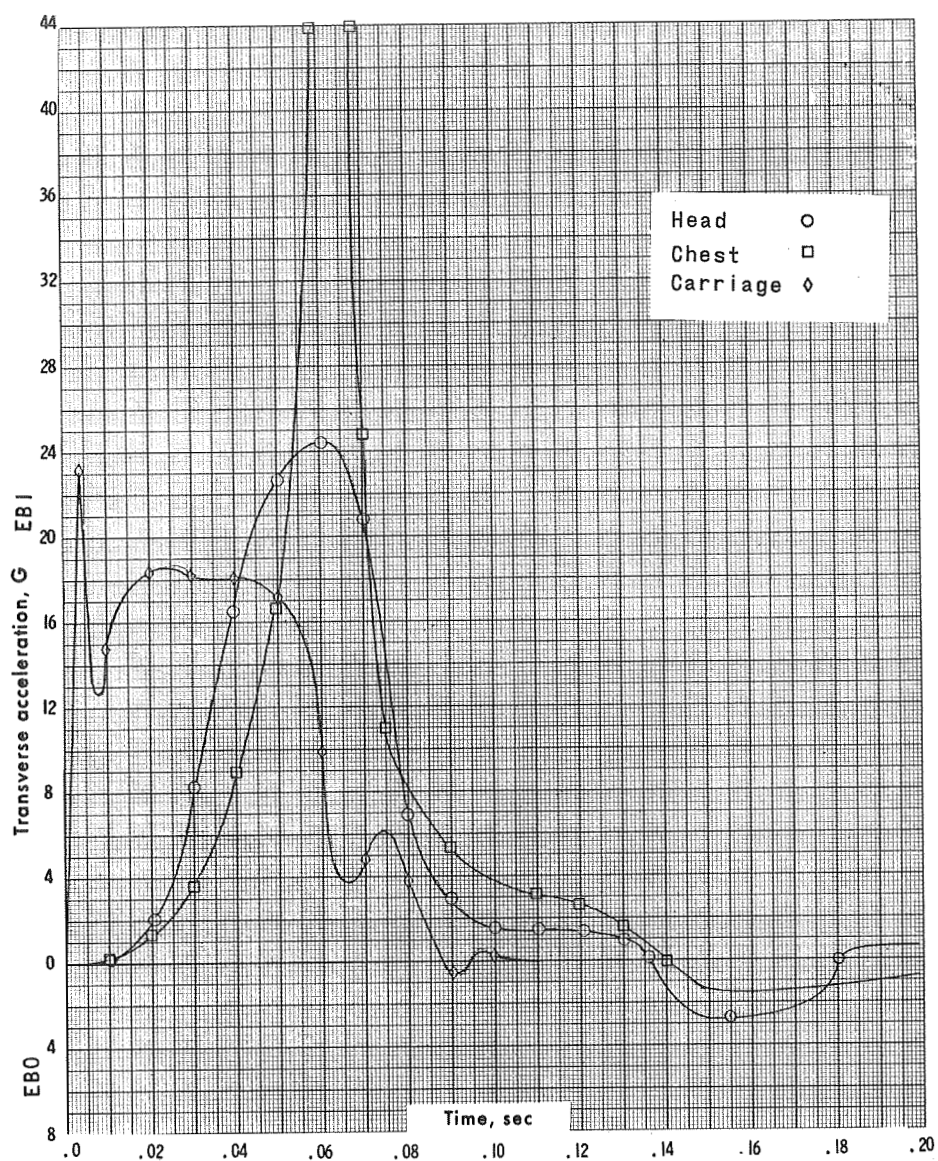
(e) Induced load 30G

Figure 15.- Continued.



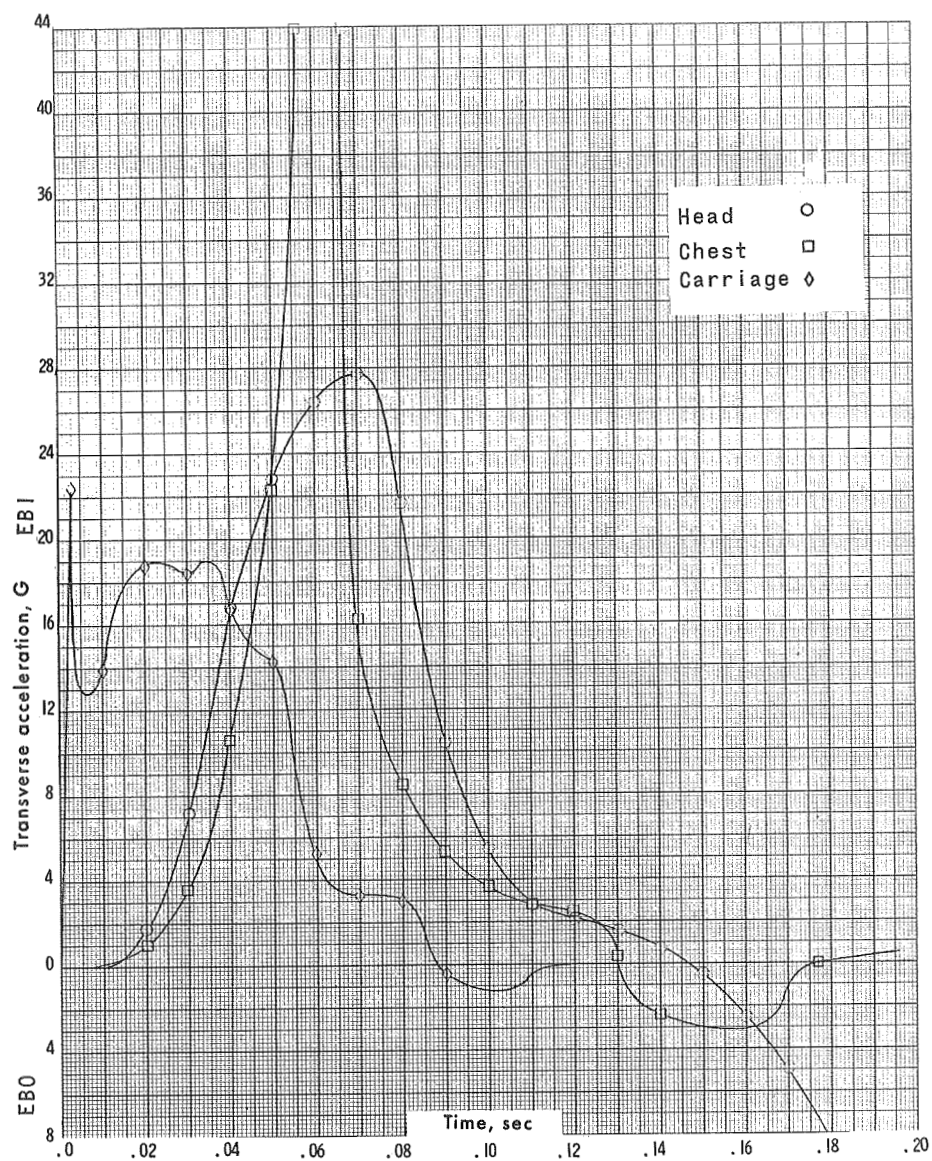
(a) Somyk type 1

Figure 16.- Acceleration-time histories measured on an anthropometric dummy using various net type body support. $V_i = 30$ ft/sec, $G = 20G$.



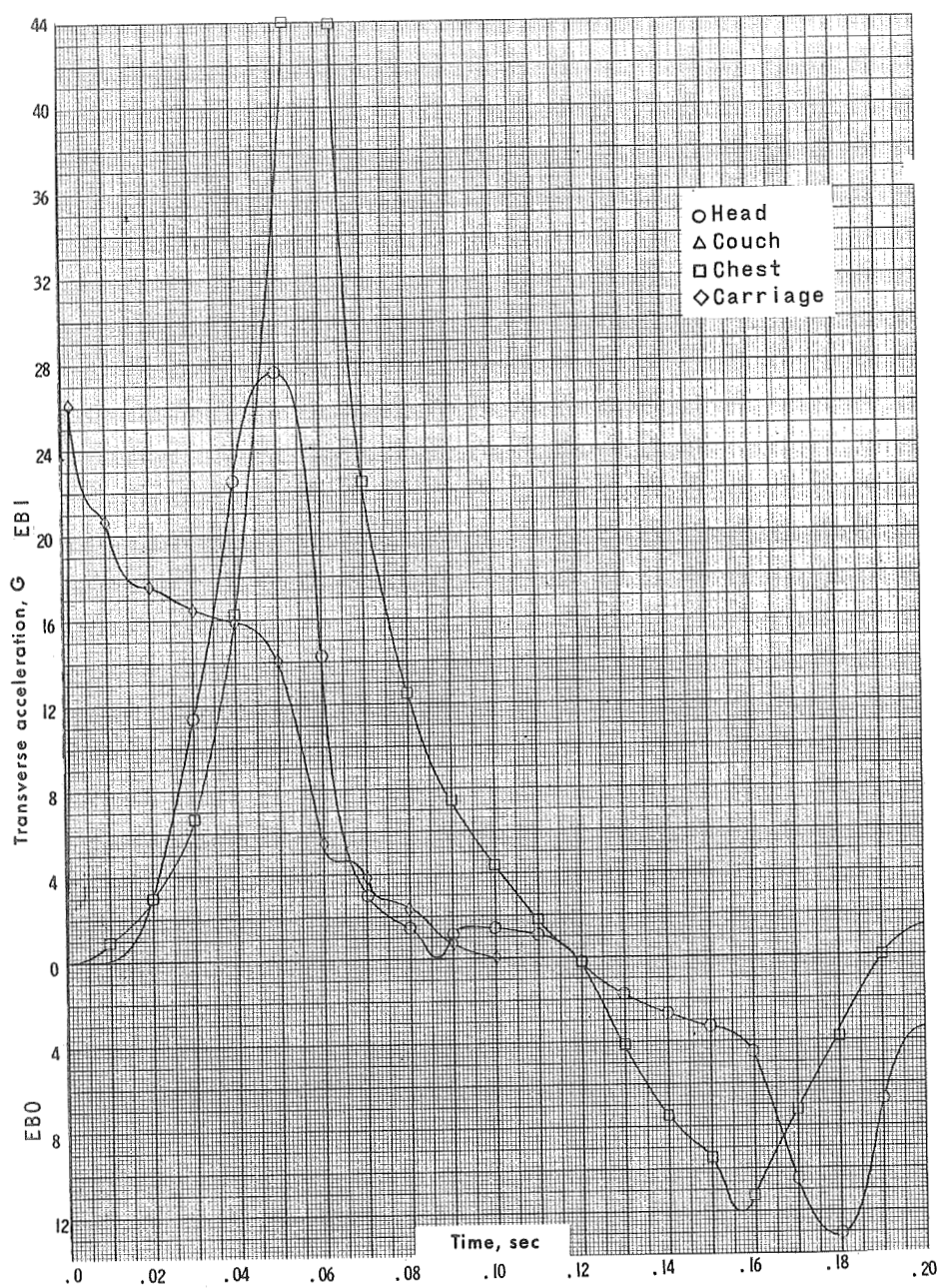
(b) Somyk type 2

Figure 16.- Continued.



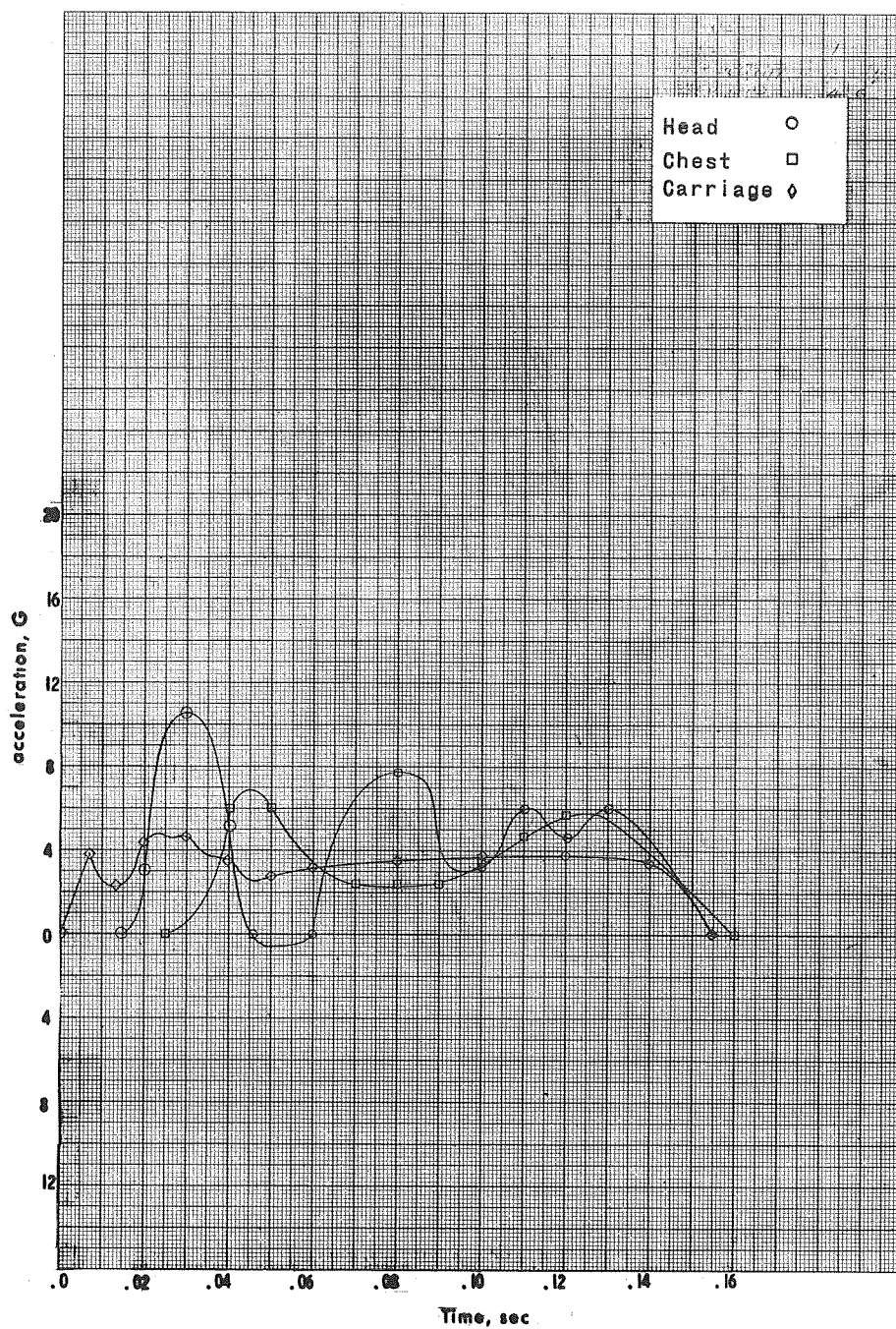
(c) Somyk type 3

Figure 16.- Continued.



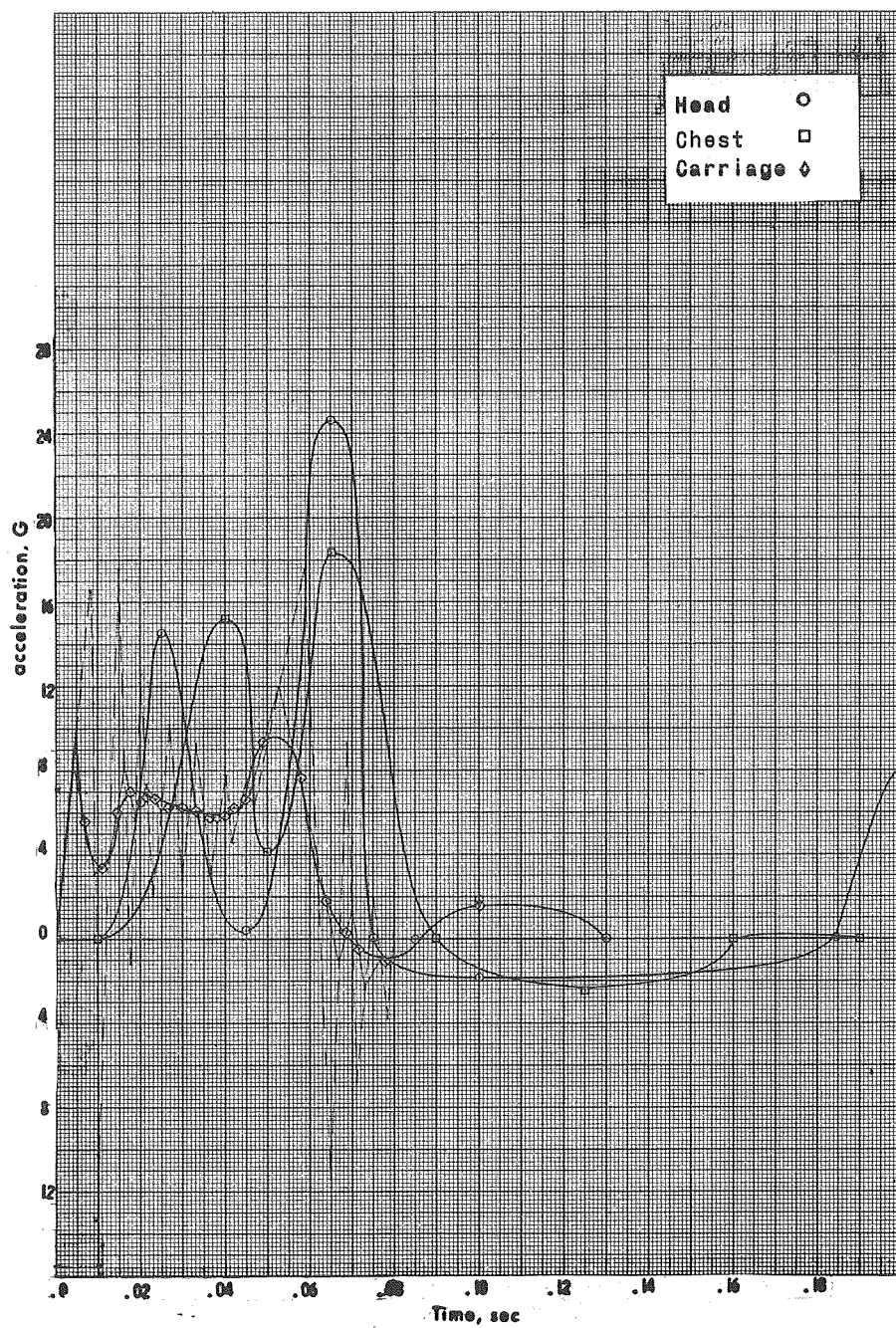
(d) Nylon Raschel

Figure 16.- Concluded.



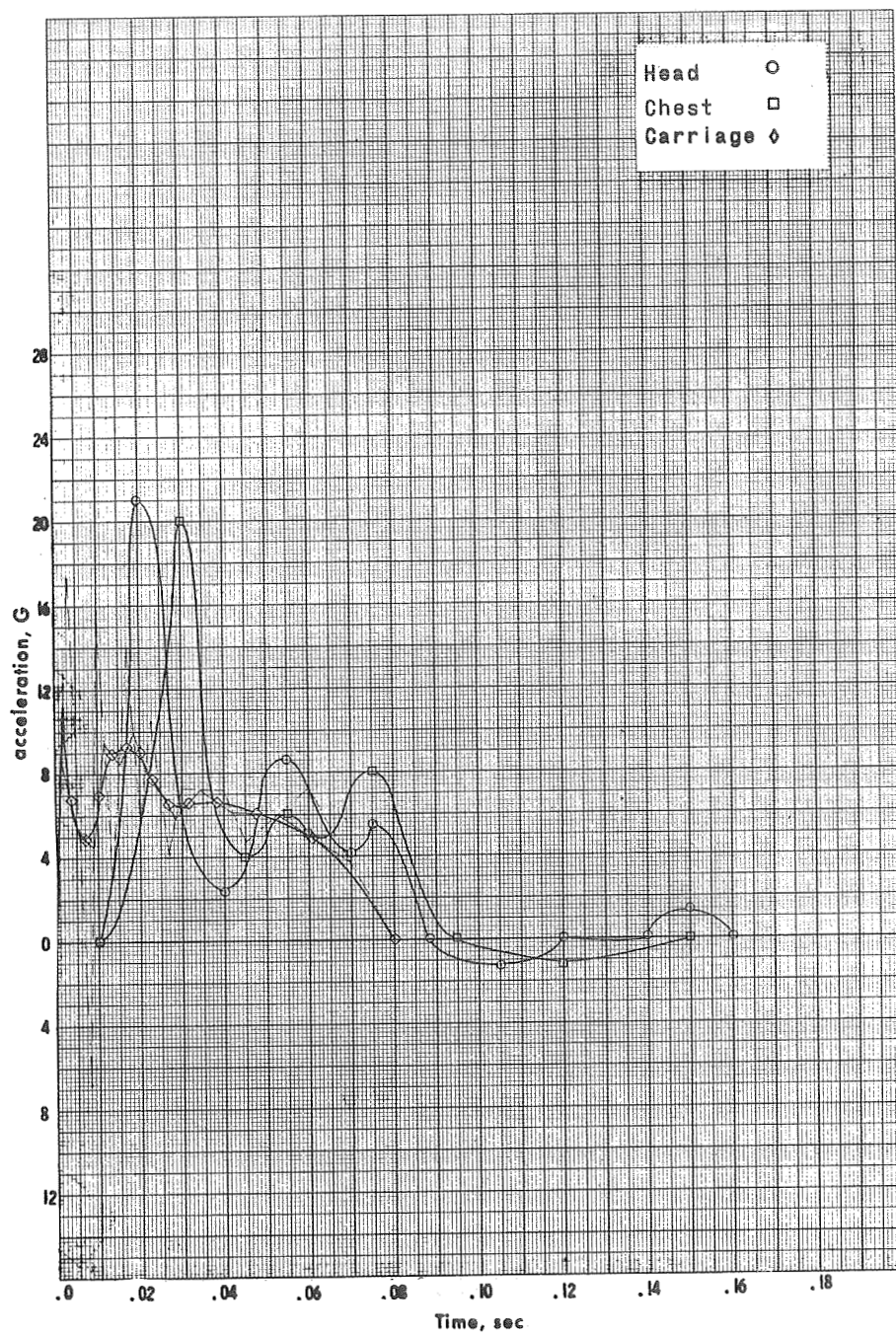
(a) Induced load 4G

Figure 17.- Acceleration-time histories measured on an anthropometric dummy using a Mercury type couch under various induced loads.
 $V_i = 13.9$ ft/sec.



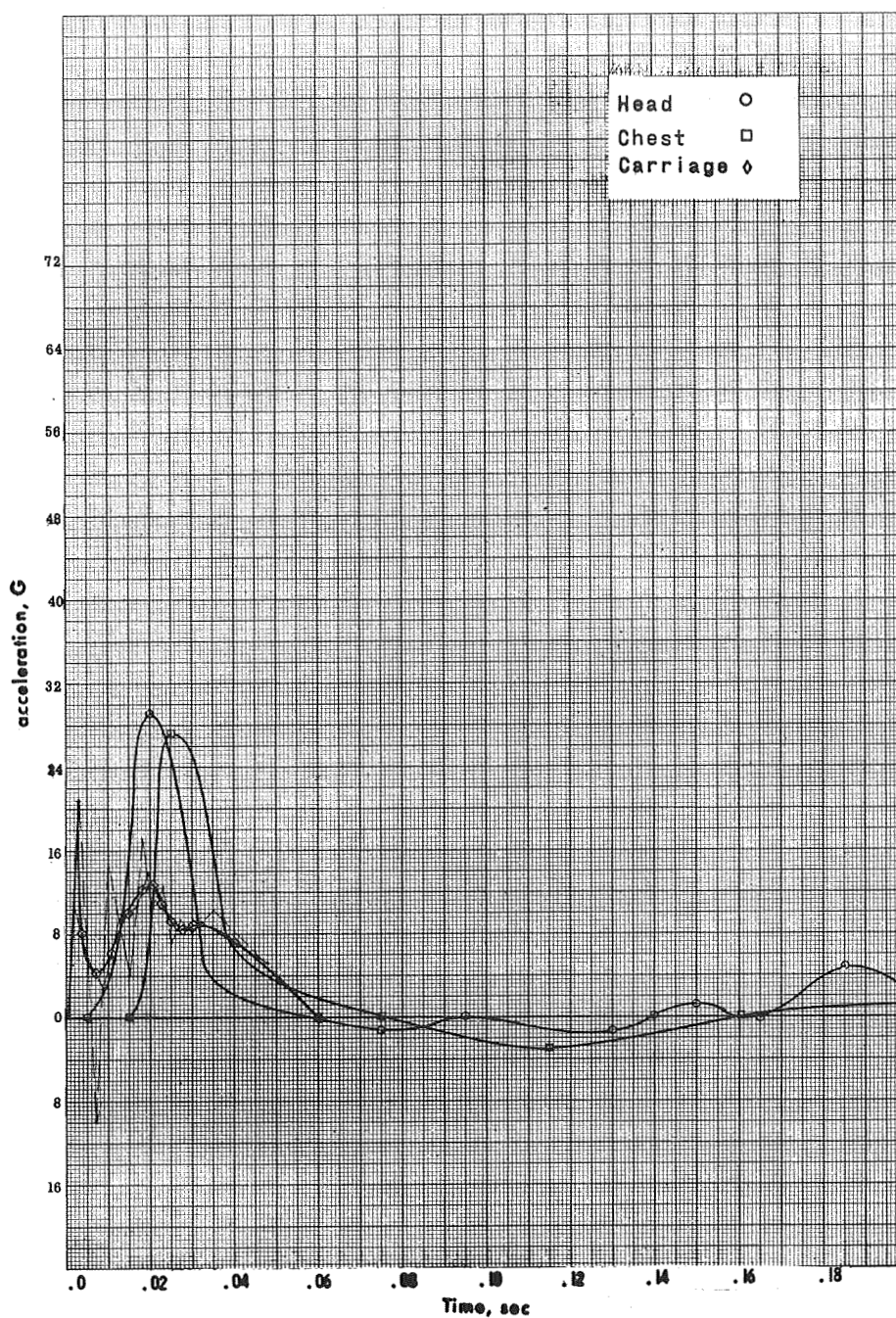
(b) Induced load 8G

Figure 17.- Continued.



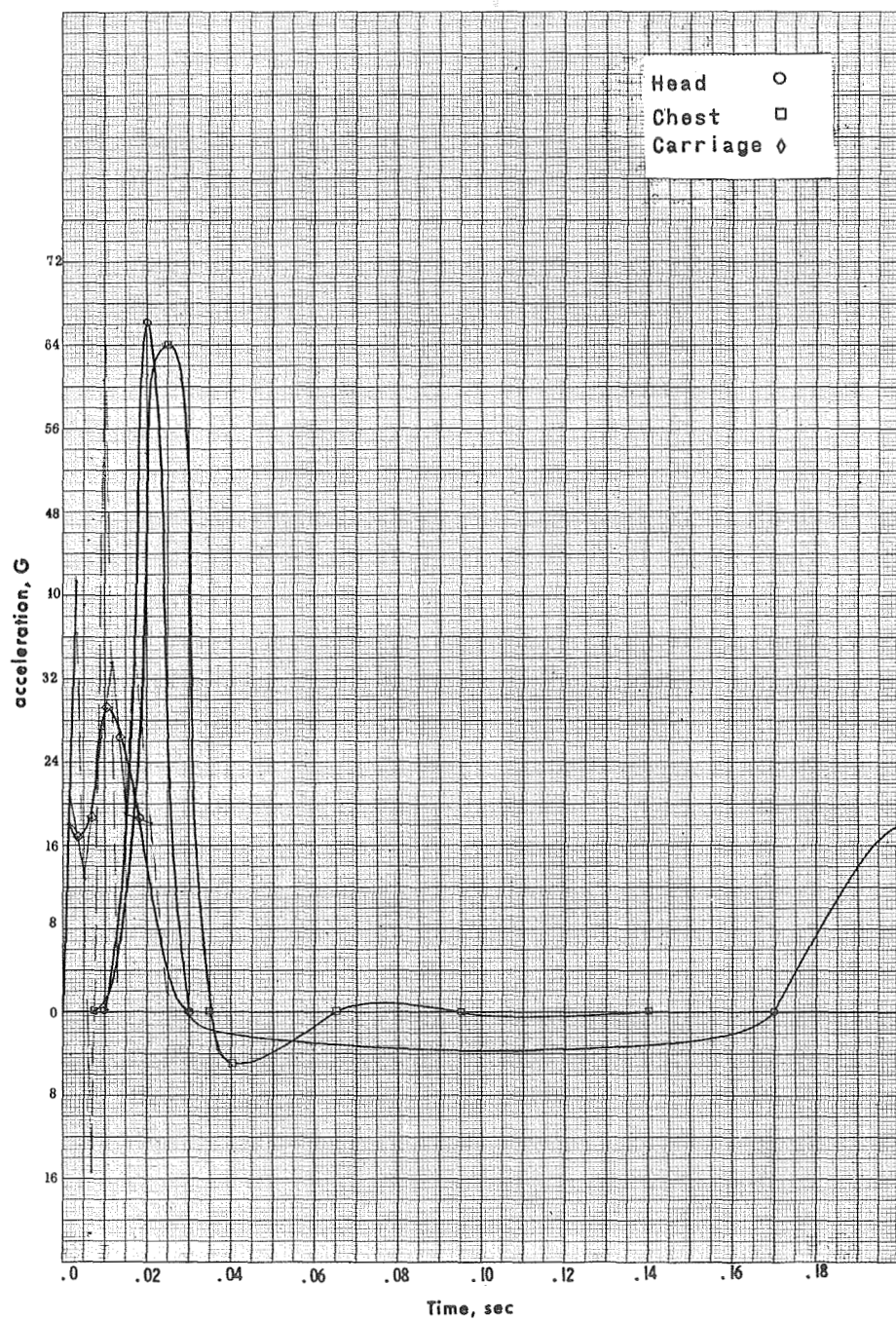
(c) Induced load 12G

Figure 17.- Continued.



(d) Induced load 16G

Figure 17.- Continued.



(e) Induced load 30G

Figure 17.- Concluded.

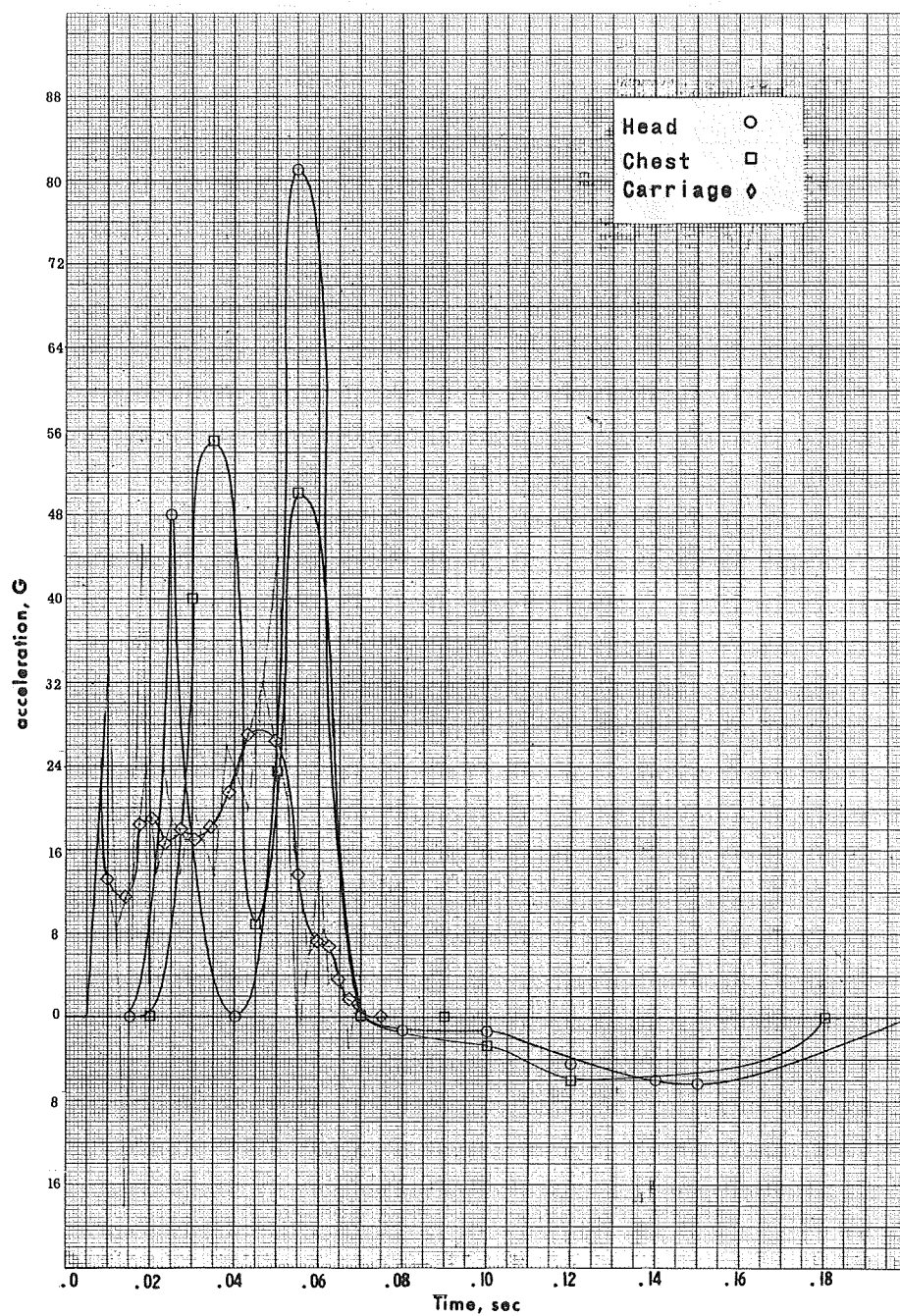
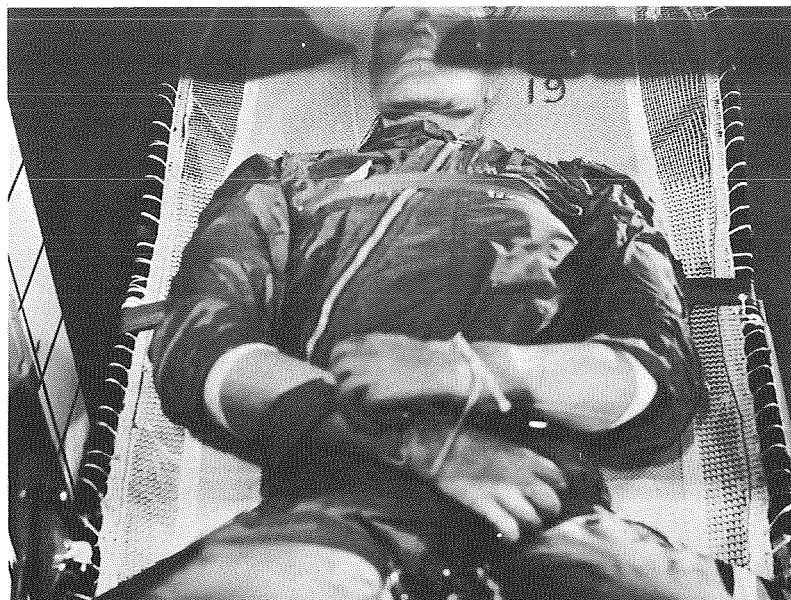
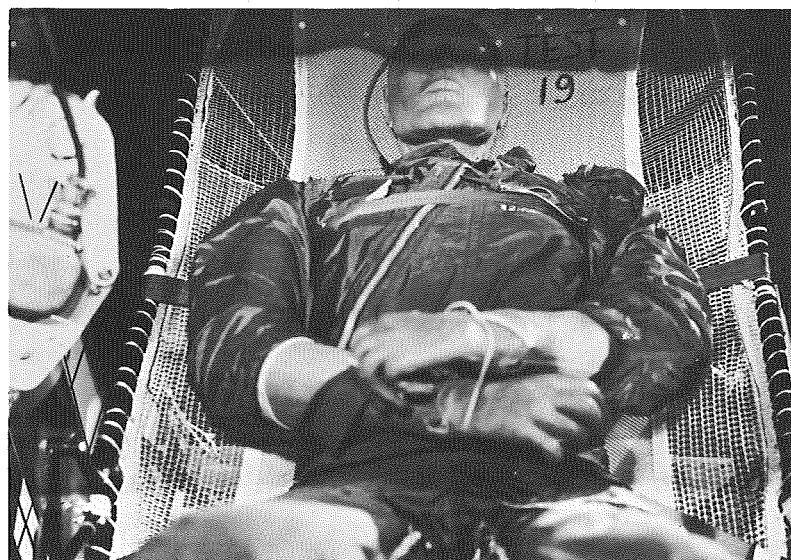


Figure 18.- Acceleration-time history measured on an anthropometric dummy using a Mercury type seat under an induced load of 20G and $V_i = 30$ ft/sec.



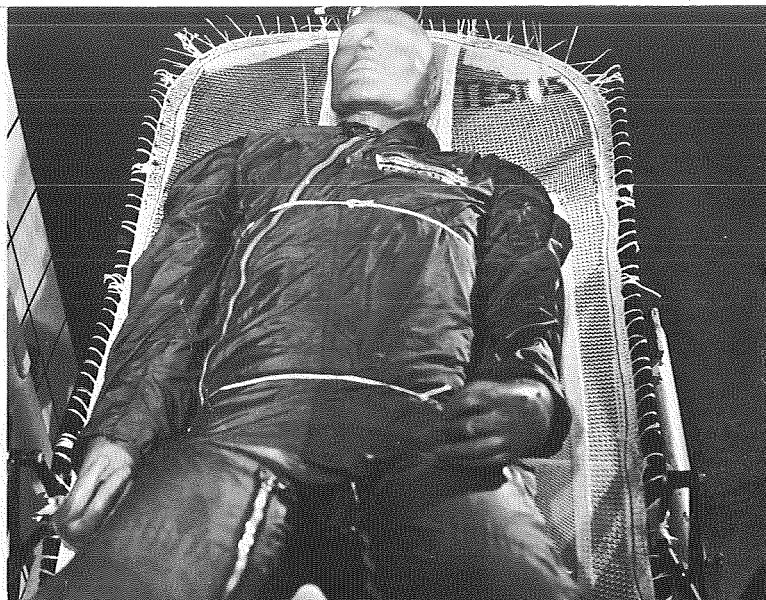
Before drop



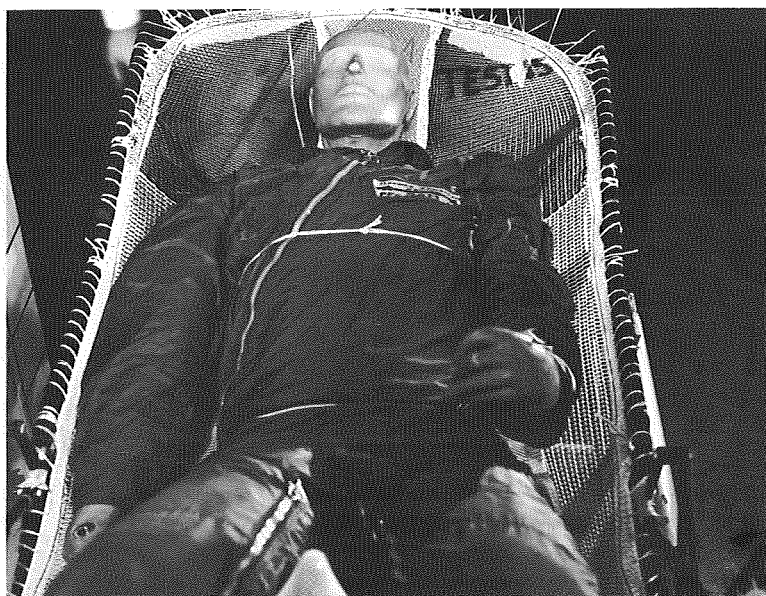
After drop

(a) Somyk 1

Figure 19.- Before and after photographs showing permanent stretching of Somyk fabric.



Before drop



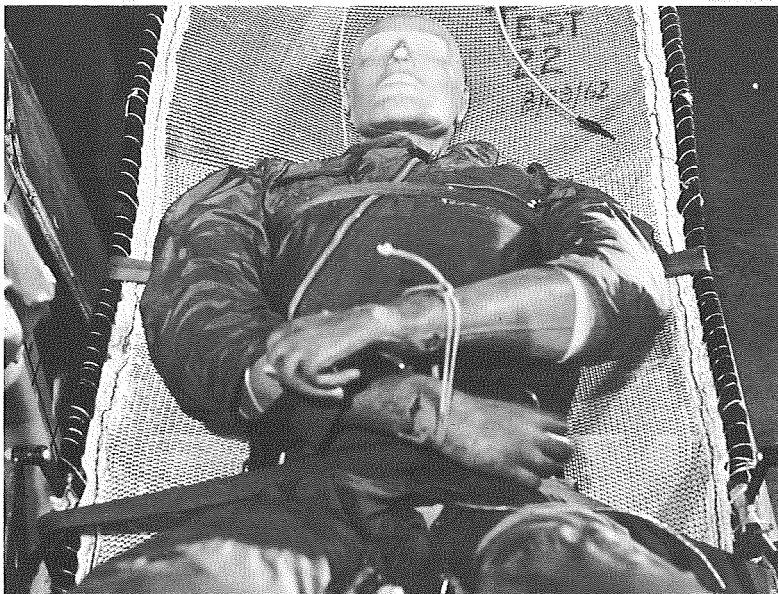
After drop

(b) Somyk 2

Figure 19.- Continued.



Before drop



After drop

(c) Somyk 3

Figure 19.- Concluded.

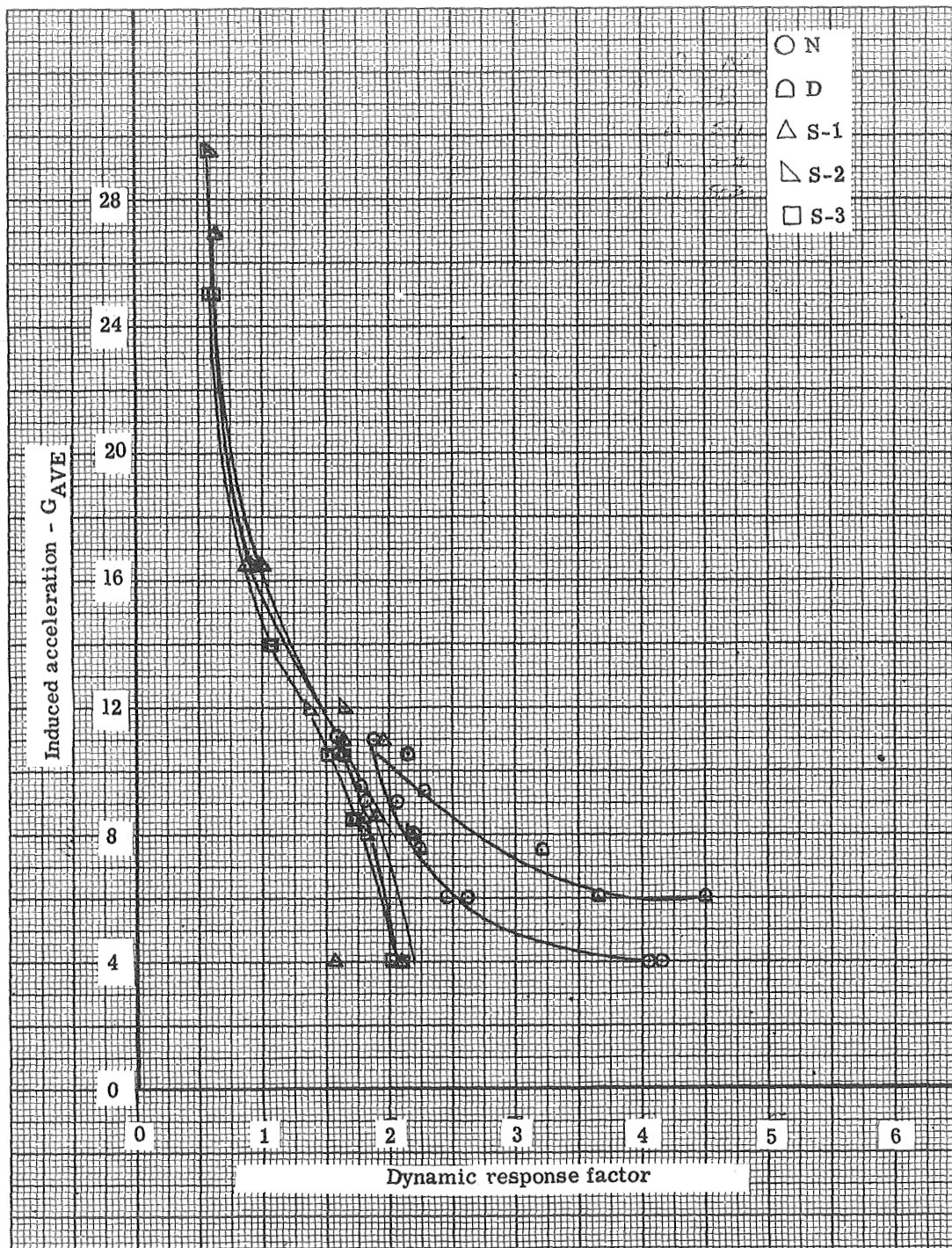


Figure 20.- Comparison of the dynamic response factors between impact surface and dummy using various net type body supports.